Heating · Piping and Air Conditioning

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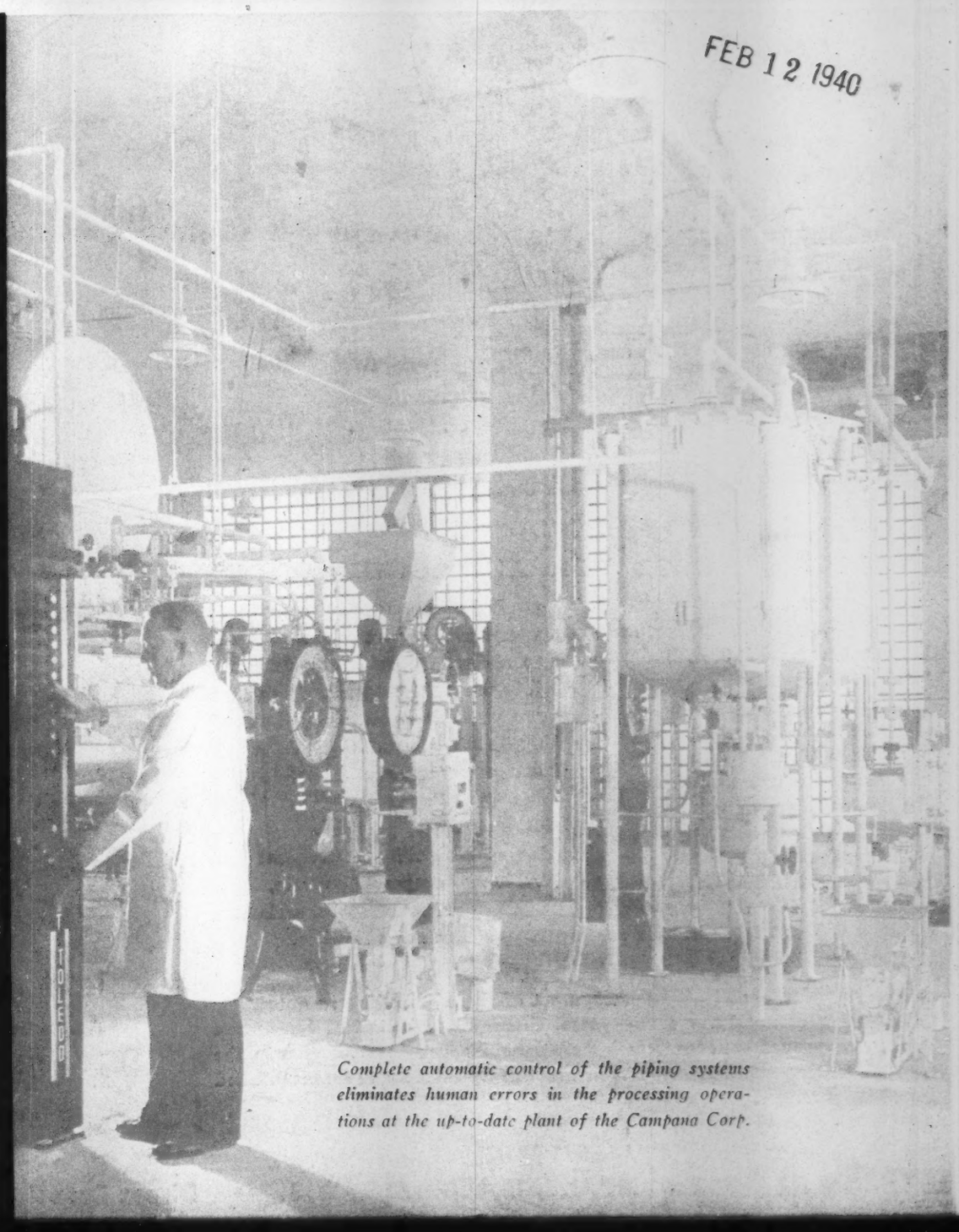
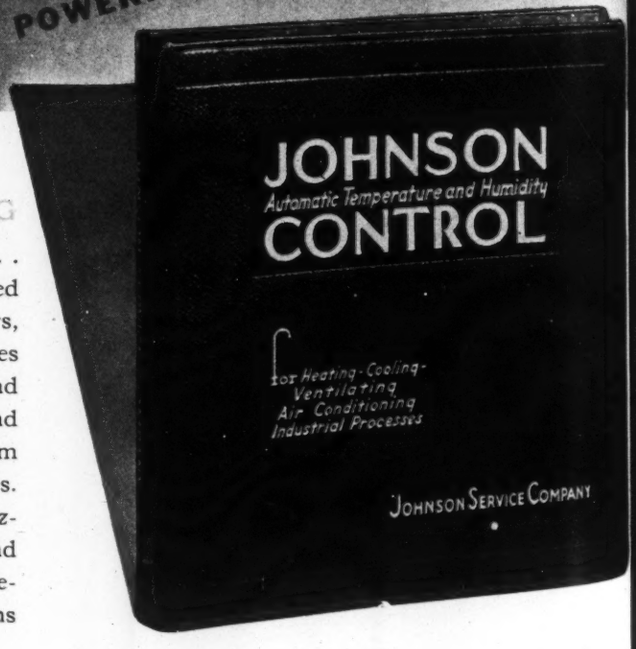


Complete automatic control of the piping systems eliminates human errors in the processing operations at the up-to-date plant of the Campana Corp.

Keep Posted on JOHNSON Gradual Contr



PROVED CONTROL FOR AIR CONDITIONING

● JOHNSON thermostats, with adjustable sensitivity, are calibrated *on the job* to balance "time lag" against the capacity of the heating, cooling, or humidifying apparatus. No "hunting" or fluctuation, when instruments are equipped with this unique feature ... Johnson "Streamline" diaphragm valves, with modulating discs, insure superior gradual control; true throttling action. The "long travel" feature of Johnson "Piston-type" damper motors is desirable for gradual movement of dampers . . . Where maximum power is required to re-position valves or dampers, Johnson "Pilot-operated" devices are available, shown at the left and upper left, above. These valves and damper motors are distinctive from the usual "spring-opposed" types. Consequently, precise synchronizing of controlling instrument and valve or damper is possible, independent of friction and of variations in pressures and velocities.

● Johnson pioneered in the development of these principles in automatic temperature control. For many years, these Johnson devices have been tested and proved on countless installations. Recent developments in the air conditioning field have won even wider acceptance for these established Johnson principles.

CONSULTING ENGINEERS
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JOHNSON Apparatus Bulletins

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Heating · Piping and Air Conditioning

with which is merged the "Aerologist"

Design, Installation
Operation, Maintenance
in Industry and Large Buildings

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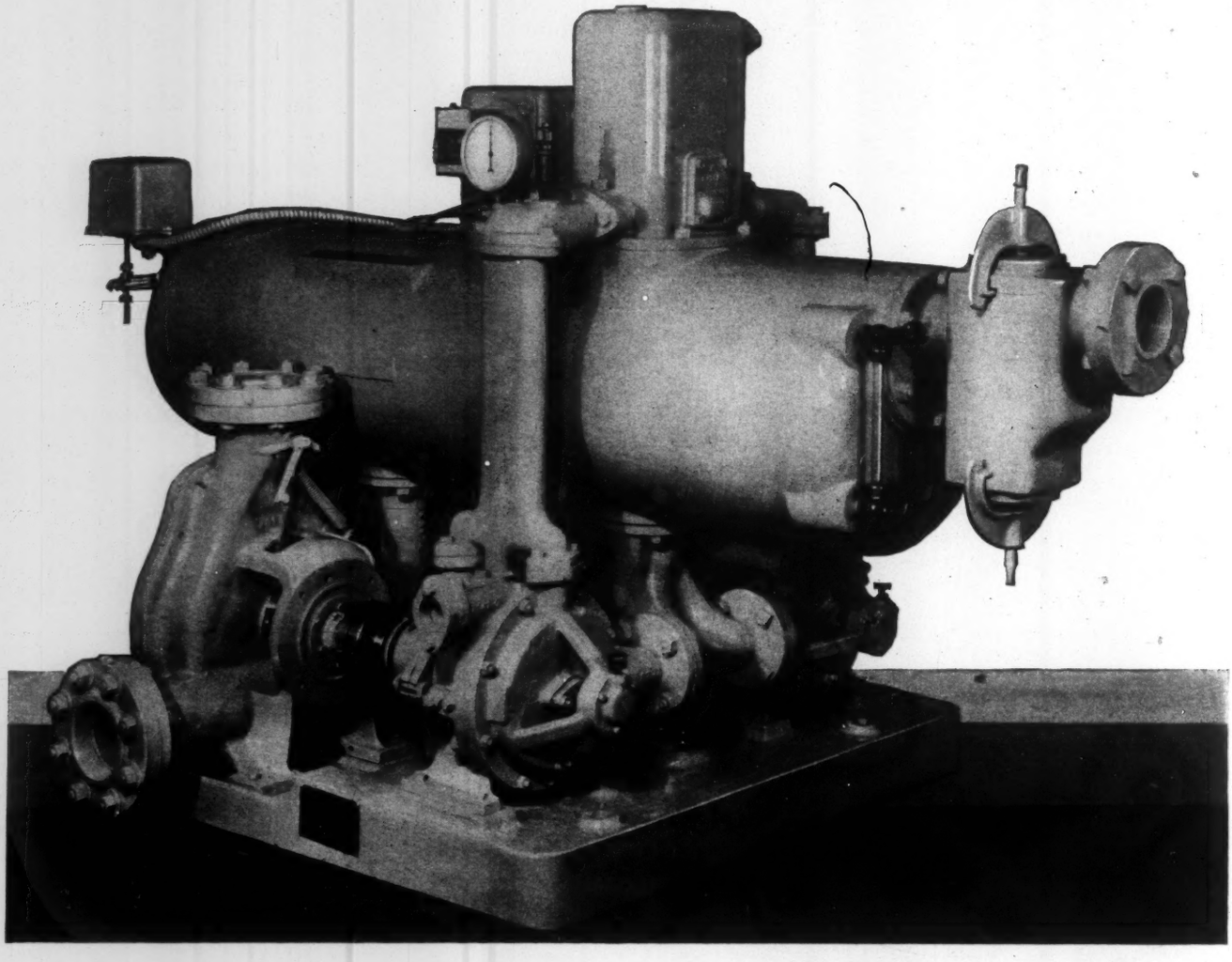
Where heat must *Not* fail... install this SAFE *Heating Pump*



In Hospitals, Greenhouses, Schools, Public Buildings, Theatres, wherever heating systems must not fail, install the Nash Vapor Turbine, for it is independent of electric current failure, and continues to operate as long as there is steam in the system. This is because the prime motive power of this economical pump is a special steam turbine, controlled by a unique "Vapor Turbine Valve", which automatically by-passes from the heating main a small portion of steam, the exact amount necessary to develop the power needed to remove the condensate and maintain the required vacuum on the system. Even this small amount is passed immediately back to the mains, and goes on to the system with little heat loss. This pump operates on any system, high or low pressure. The Vapor Turbine is a most economical pump, for the elimination of electric current does away with current cost, the largest single item in the operation of an ordinary return line heating pump.

BULLETIN ON REQUEST

THE NASH ENGINEERING COMPANY
221-A WILSON ROAD, SOUTH NORWALK, CONNECTICUT

THE EDITOR'S PAGES

CONVENTIONS AND EXPOSITION AT CLEVELAND MEET ALL EXPECTATIONS

The annual meeting of the American Society of Heating and Ventilating Engineers, the International Heating and Ventilating Exposition, and the other events held at Cleveland the week of January 22-26 were among the most successful affairs of the kind ever held, according to those who attended the functions. Registration for the ASHVE gathering was over 1000, approaching closely the all-time record, and the exposition, held in Lakeside Hall, was a sell-out. The displays seemed particularly attractive and informative, and a number of new developments were introduced. Well-planned (and attended) evening social affairs and plant inspection trips during the few available spare daytime hours rounded out a busy week.

The proceedings of the ASHVE meeting will appear as usual in the Journal Section next month. New products shown at the exposition which have not already been covered in our regular Equipment Developments columns will be described there; some appear this month.

A complete program, exhibitors' list, and other information about the big week in Cleveland was presented in the Show Section of the January HPAC, which was mailed to all subscribers well in advance of its opening.

LAUER HEADS YORK ICE

Announcement was made last month following the annual meetings of the stockholders and directors of the York Ice Machinery Corp. that the growth in volume of the company's business during the past year and at an increasing rate during the past few months necessitated certain official changes.

William S. Shipley, president of the corporation for the past 10 years, was elected chairman of the board of directors and Stewart E. Lauer, formerly vice-president, was elected president. Elmer A. Kleinschmidt was elected executive vice-president and Llewellyn Williams, vice-president in charge of engineering. Samuel J. Shipley was elected vice-president and treasurer, and Vincent K. Keesey was elected secretary.

The steps which have been taken will add to the efficiency of the organization and at the same time will bring some of the younger men to the front, Mr. Shipley stated.

ILLINOIS INSTITUTE APPOINTS YELLOTT

John I. Yellott has been appointed professor and director of mechanical engineering at Armour Institute of Technology, effective September 1. Operation of the new Illinois Institute of Technology—the engineering school brought about by the merger of Armour and Lewis Institute—begins in September.

Mr. Yellot, who is now with Stevens Institute of Technology, has done research in high velocity steam and air flow, and is the author of numerous papers and discussions in this field.

REVISED RATINGS FOR MULTIPLE V-BELTS

Based on studies of belt life made by Allis-Chalmers Mfg. Co. engineers, in conjunction with industry representatives, the power ratings of multiple V-belt drives have been revised to provide maximum belt life, it was announced last month. Sheave diameters and correction factors are now standardized according to formulas based on results with multiple V-belt drives over a period of 10 years, and overload factors are being arranged also to allow for the type of prime mover and driven machine.

The new ratings provide in many cases for a more compact drive and for long belt life at low initial cost, according to the announcement.

5119 PULLMANS AIR CONDITIONED

At the end of the calendar year 1939, the Pullman Co. had 5119 cars equipped with air conditioning apparatus, of which 4831 were of the conventional type to which air conditioning systems were applied after the cars had been built and in service for some years. The remaining 288 cars were of modern, lightweight, streamline construction in which the air conditioning feature is an integral part of the car as built.

Total cost of applying air conditioning to the 4831 cars exceeded $33,500,000, an average cost of about $7,000 per car. Exact cost of the air conditioning for the 288 lightweight units is not easily available due to the fact that the air conditioning was included as an integral part of the car.

SALES INCREASES REPORTED

Sales volume of the York Ice Machinery Corp. for the first quarter of its current fiscal year was 47 per cent ahead of the same quarter for the preceding year, reports William S. Shipley. Orders booked for the three months ending December 31, 1939, were $3,588,629. The additional business is partly the result of increasing activity in the field of large-scale air conditioning, according to Mr. Shipley.

Orders received by General Electric Co. during the fourth quarter of 1939 amounted to $112,166,535, an increase of 77 per cent over the final quarter of 1938, President Charles E. Wilson announced last month. Orders for the year 1939 were $360,748,386 compared with $252,-176,223 for 1938, an increase of 43 per cent.

While final figures are not yet available, every indication is that stoker sales in 1939 broke all existing records, according to the Committee of Ten. This is based on the fact that sales in November, 1939, exceeded sales for the same month in both 1938 and 1937 and reports from manufacturers on December sales indicate as high a unit volume as in the past two years, thus assuring a slight gain over the record year of 1937, as well as a gain of about 10 per cent over 1938.

Total factory sales for the first eleven months of 1939 were 98,277 compared with 91,462 for the corresponding period in 1938 and 97,199 units in the same months of 1937.

RIVER BOAT AIR CONDITIONED

An air conditioning system with a cooling capacity equal to that of the liner Normandie is a feature of the new Streckfuss streamlined excursion steamer to be put into Mississippi River service next June at St. Louis, Mo.

Two decks of the steamer's five will be completely enclosed for air conditioning. These consist of a main deck or dance floor to accommodate 2500 dancers, and a mezzanine or balcony floor for dining tables.

The air conditioning system is to be zoned so the equipment will distribute cooled, dehumidified air evenly throughout the decks, despite the direction of the sun on the steamer, according to Carrier Corp. The boat is constructed of steel with walls insulated with rock wool.

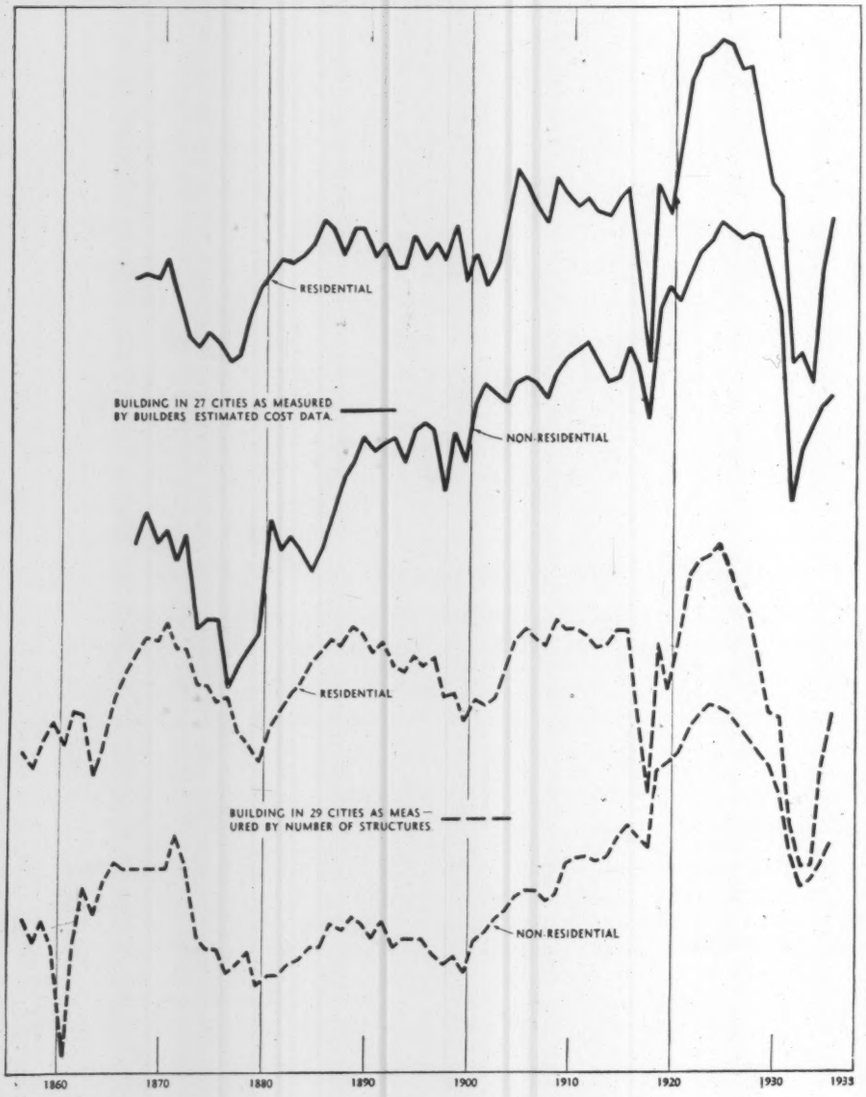
ECONOMIST PRESENTS HIS VIEWS ON HOW BUILDING IS AFFECTED BY WAR

Writing in a recent issue of *Dun's Review*, Prof. Clarence D. Long, Jr., of the economics department at Wesleyan university, analyzed the building industry as a "maker and breaker of booms and depressions" in business. His concluding paragraphs are of particularly timely interest, and therefore are given here through the courtesy of the publisher and the author, together with the accompanying chart:

"Does the pattern followed by building in previous wars provide a clue to behavior of building in the present war? Has the great building inactivity in the last 10 years developed such an urgent demand that war will be powerless to depress building? The answer to this would seem to depend upon the part which America plays in the conflict. So long as the United States remains at peace and keeps her trade with belligerents within bounds, the volume of building may continue the upward course of the last five years. If munitions trade remains on a cash-and-carry basis, trade with the belligerents is not likely to become great enough to disrupt our economy.

"On the other hand, if the United States enters the war, opens her trade up to the allies on a credit basis, or engages upon a gigantic armament program of, say, five or ten billions a year, then even our great need of housing will not prevent a slump. For the things that are used in war are the things that are used in building: men, metals, cellulose, transportation, on the one hand; savings on the other. Since there are never enough of all these things to carry on a building program and a major war at the same time, the war will always receive priority."

(Semi-logarithmic chart, equal vertical distances show equal percentage changes; cities are in general the most populous ones, account for a substantial part of all building.)



AIR CONDITIONING ASSOCIATION FORMED

One of the features of the refrigeration and air conditioning meetings and exposition held in Chicago during the week of January 15 was the formation of the National Air Conditioning Association, the announced purpose of which is to advance the further development of the air conditioning industry in the interest of public service. The president of the new group is Jesse W. Page, Jr., of Page-Williamson, Inc.; the vice-president is J. N. Sprekelmeyer of General Engineering Corp.; the treasurer is J. H. Keller of Mechanical Heat & Cold, Inc. In addition to the officers, the board of directors includes A. C. Buensod of Buensod-Stacey, Sam Shure of Natkin & Co., E. R. Cooney of Cooney Refrigeration Co., Alfred Epstein of Independent Refrigeration Co., Fred A. Hessick of Combustioneer Corp., and M. S. Lebair of York Ice Machinery Corp. The executive secretary is Albert L. Maillard, and offices of the association are to be established at Kansas City, Mo.

At the organization meeting it was stated that the air conditioning industry should "present a united and intelligent front to the public to sell air conditioning" and that because a bad job hurts everyone, standards should be established. Applications for 37 charter memberships were read at the organization meeting.

PLANT OPEN HOUSE ATTRACTS 1500

More than 1500 guests—employees, their families, their neighbors, and their friends—swarmed through the factory and offices of the Young Radiator Co., Racine, Wis., on a recent afternoon, the occasion being a plant "open house." Many industrial organizations are finding such affairs to be worthwhile in promoting understanding of their products, plants and purposes on the part of their workers and neighbors. The idea was conceived by Pres. Fred Young in an effort to acquaint department workers with all the work in the plant, and to reveal the importance of each employee's rôle.

UNIT HEATER GROUP ELECTS OFFICERS

The Industrial Unit Heater Association elected C. C. Cheyney, president; Albert J. Nesbitt, vice-president; and L. O. Monroe, secretary-treasurer at its annual meeting in Cleveland on January 22.

The response to the standardization program initiated three years ago has encouraged the association to enlarge the scope of this work. The engineering committee has planned a definite program for 1940 covering further standards.

MODERNIZED HEATING CUTS STEAM COSTS ON LEXINGTON AVE.

Webster Moderator System Heats 16-Story Office Building of Large Eastern Railroad

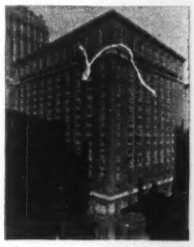
COSTLY CHANGES ARE AVOIDED

Contract Is Paid in Full After Completion of Two Year Study of Steam Heating Results

ENDS HEATING DIFFICULTIES

New York, N. Y.—When the real estate division of a large Eastern Railroad acquired a 16-story property on Lexington Avenue, there were certain unsatisfactory features in the heating of this building.

The principal difficulty lay in the fact that the vertical risers supplying steam to the heating system were small. The cost of correcting this condition in the normal way by installing new, larger risers would have been extremely expensive.



466 Lexington Avenue Building, New York

After considerable study of the problem, the Building Management decided that a Webster Moderator System would end their heating difficulties without costly changes in the original heating installation. It was agreed that payment for Webster equipment and service would be realized out of the steam savings effected.

In two years, the success of the installation was established and shortly after the contract was paid in full.

With the Webster Moderator System this large New York building receives satisfactory heating with comfortable temperatures and minimum steam consumption.

WEBSTER PRODUCTS AND SERVICES

Vacuum and Vapor Systems of Steam Heating, Central Heat Controls, Heating Modernization Programs, Concealed (non-ferrous) Radiation, Radiator Valves, Thermostatic Traps, Drip Traps, Dirt Strainers, Boiler Protectors, Boiler Return Traps, Vent Traps, Damper Regulators, Lift Fittings, Expansion Joints, Vacuum Governors, Air Separating Tanks, Process Steam Traps, Webster-Nesbitt Unit Heaters and Conditioners.

L. C. SMITH & CORONA TYPEWRITERS, INC. CUTS HEATING COSTS

Webster Moderator System Helps Groton, N. Y. Plant to Slash Coal Consumption 20 P.C.

SAVES $1,151.83 IN ONE YEAR

Maintains Desired Temperatures in Manufacturing and Storage Sections, Offices, Gymnasium

COMFORT IN COLDEST WEATHER

Groton, N. Y.—Coal consumption in the Groton Plant of L. C. Smith & Corona Typewriters, Inc., has been reduced approximately 20 per cent as the result of a Webster Heating Modernization Program.

A preliminary survey of the heating system in this modern plant was carried out in 1937. As a result, a Webster Moderator System of Steam Heating was installed to correct steam circulation difficulties and cut fuel costs.

The new Corona Typewriter

The Webster Moderator System maintains desired temperatures in manufacturing sections, offices, storage sections, gymnasium and club rooms.

It was originally planned to allow the modernization program to pay for itself out of fuel savings. After two years of satisfactory results, it was decided to close the transaction for cash.

There is a total of 20,673 sq. ft. of installed direct radiation in the Groton Plant of L. C. Smith & Corona Typewriters, Inc.

A feature of the modernization program was the equipping of 24 coils with Webster Process Steam Traps and Webster Dirt Strainers.

MODERN TRAPS FOR KITCHEN EQUIPMENT ON PENNSY DINERS

Pennsylvania Railroad Installs Webster Traps in Kitchens of Four Twin-unit Dining Cars

STEAM WASTE IS PREVENTED

Steam-using Coffee Urns, Sinks, Warming Ovens Achieve Kitchen Operation at Top Efficiency

ALL HOT FOODS SERVED HOT

Altoona, Pa.—While four twin-unit dining cars of the Pennsylvania Railroad were being modernized here in the summer of 1939, the latest-type Webster Process Steam Traps were installed on all steam-using kitchen equipment.

Wherever these modern dining car kitchens use steam for process, Webster Process Steam Traps were installed.

In this modern dining car kitchen of the Pennsylvania Railroad, Webster Process Steam Traps are installed on all-steam-using coffee urns, sinks and warming ovens.

Webster Traps are in use on the steam lines from coffee urns, sinks and warming ovens. They assure automatic, complete and continuous discharge of air and water of condensation.

Webster Trap used on kitchen equipment in Pennsy R. R. diners

Heating dollars go farther with Webster Process Steam Traps because steam is held back until it gives up its useful heat. Heating-up time is shortened and the production rate of machines is speeded up.

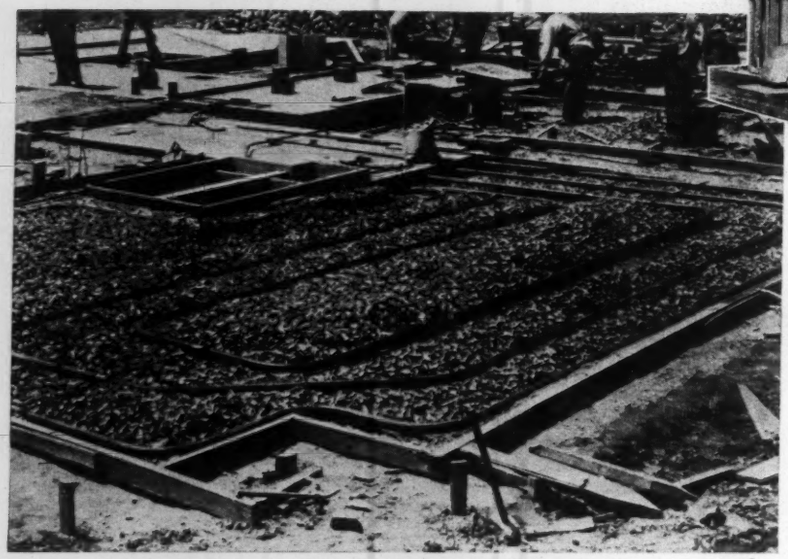
Two of the modernized diners are dining-dormitory cars operated between New York and Chicago. The other two are dining-kitchen-lunch counter cars operated between New York and Washington.

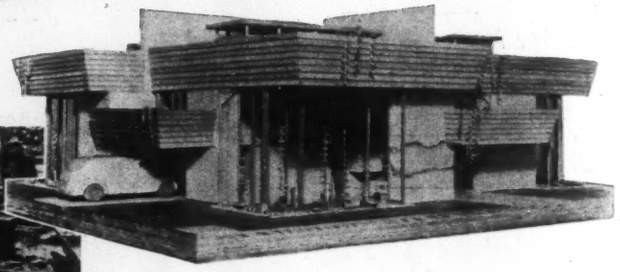
The cooperation and services of the Webster Organization are freely offered to help you pre-determine the extent of savings and improved steam heating service with Webster Heating Modernization Programs.

WARREN WEBSTER & CO., CAMDEN, N. J. EST. 1888

Pioneers of the Vacuum System of Steam Heating. Representatives in 65 principal U. S. Cities

Another RADIANT HEATING Installation using BYERS WROUGHT IRON





- SUNTOP HOMES
  ARDMORE, PA.
- FRANK LLOYD WRIGHT,
  ARCHITECT

Corrosion costs You more than Wrought Iron

Suntop Homes, an innovation in the multiple housing field, is equally modern in its heating system. Steam generated in a small basement furnace room is circulated through 175 feet of Byers Wrought Iron pipe coils, laid in gravel under the concrete floor of the living room, store room and carport. This type of radiant heating was also used by Frank Lloyd Wright, the architect, in the S. C. Johnson & Sons, Inc., office building at Racine, Wis.

In installations of this sort, pipe life is of vital importance, since repairs or replacements would be very difficult. Any necessity for costly experiments in selecting material is eliminated, however, because of the known service life of Byers Wrought Iron under similar conditions. The superior corrosion resistance of wrought iron in heating service has of course been demonstrated in thousands of applications throughout the country. The performance of wrought iron in this type of installation, from the standpoint of exposure to wide variations in temperature, could be safely predicted from its outstanding record in skating rink installations.

You may have some "new" corrosion problem for which past experience in some parallel service will provide the answer. If you will write details, our Engineering Service Department will: (1) Determine the probable corrosive conditions; (2) Relate these to parallel conditions encountered elsewhere; (3) Interpret the results in the light of 76 years experience with corrosion problems, and (4) Make recommendations . . . supported by service records. Ask, too, for our bulletin, "Wrought Iron in Piping Systems."

A. M. Byers Company, Pittsburgh, Pa. Established 1864. Boston, New York, Philadelphia, Washington, Chicago, St. Louis, Houston, Seattle, San Francisco.

Specify Byers Genuine Wrought Iron Pipe for corrosive services and Byers Steel Pipe for your other requirements.

BYERS
GENUINE
WROUGHT IRON
Tubular and Flat Rolled Products

Heating · Piping and Air Conditioning

Vol. 12, No. 2 • *February, 1940*

How to Figure the Cost of a Process Piping Shutdown

By **A. C. Kirkwood***

SORRY, Chief, looks like No. 2 kettle will be out of service until the boys can shut down the steam supply line Saturday."

"Now listen, Gard, that kettle goes back in service today. We have to run it every day and night this week to meet the shipping date on the Tucker order. We can't afford any outages."

"But Chief, that valve is haywire and the only way to get at it is to kill the entire steam header to Department D. Kill the header and all six kettles are out for about half a day. Now if the Old Man would have let me have the header and valves when they built the line . . ."

* * *

How many times have you heard this same discussion? Sounds like a valve salesman's plea, and it is; but the salesman is probably the maintenance foreman, a department chief, or some other employee who faces facts in the raw with a wrench in one hand and a production schedule in the other.

Too often valves are counted as luxuries during the design and erection of a plant. Many are, but let us look into this matter to see where valves are necessary and why. Perhaps our friend Gard has a typical problem.

The steam line supplying the kettles is a typical installation—a gate valve at the branch from the main header supplying various plant departments, a run of pipe passing all kettles with a branch to each. The individual kettle lines contain the regulating valves and a shut off valve of the gate type. Failure of one of the kettle valves (gates) will involve service to all kettles.

What improvements can be made to this layout to increase reliability? What changes should be considered to insure minimum outage time—time that is so vital to all industries and particularly to some in these days of better business outlook?

Several methods are available, each with some point of merit to distinguish it from the others so that it will appeal to the owner, the manager, the operator, or the maintenance man. Where these several opinions focus depends upon the value of the product, the cost of the investment, and the results obtained.

Perchance a little alphabetical arithmetic will help disclose whether Gard was right in asking for more header and valves, or whether the management was correct in holding the investment cost down when the plant was built. The management advises that the product of this department is worth A dollars per year to the company based on their intended operating schedule of 6000 hr per year.

Obviously a shutdown of all kettles for 1 hr means a loss of $A/6000$ dollars and the 4 hr shutdown mentioned by Gard means a loss of $(A \times 4)/6000$ or $A/1500$ dollars. Suppose only three kettles were shut down during the 4 hr repair period— then the loss would be cut to $A/3000$ dollars. Likewise the loss would be cut to $A/4500$ if only two kettles were cut out during repairs.

What's the cost of a piping shutdown made necessary when a valve needs repairing? How much money is it economical to spend to sectionalize the steam header so that the whole department won't have to stop operations because one valve has gone bad? How does the value of the product affect the answer? . . . . These are the questions answered by Mr. Kirkwood, who explains how to estimate the cost of a shutdown and how to choose a suitable piping investment in line with the savings it can be expected to give. . . . . Valves too often are considered luxuries when a plant is designed and erected; sometimes they are, but many times they are profit-producing necessities. . . . . The question is vital to almost any plant, and particularly to some in these days of better business outlook

*Burns & McDonnell Engrg. Co., Consulting Engineers.

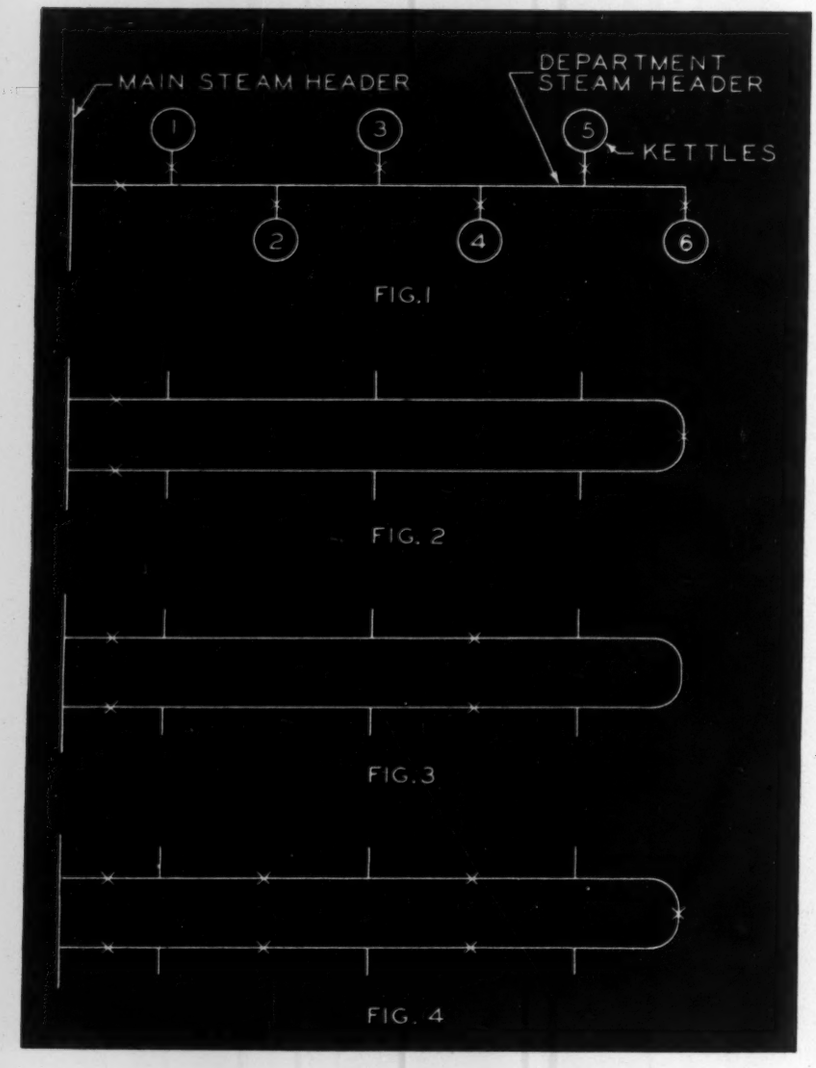
Table 1—Losses for Various Outages Based on Product Value

Number of kettles	6
Annual product value	A
Hours operation per year	6000
Loss per hr, all six kettles	$A/6000$
Loss per hr, one kettle = 1/6 ($A/6000$)	$A/36000$
Losses for 4 hr Outages	
One kettle out = 4 ($A/36000$)	$A/9000$
Two kettles out = 2×4 ($A/36000$)	$A/4500$
Three kettles out = 3×4 ($A/36000$)	$A/3000$
Four kettles out = 4×4 ($A/36000$)	$A/2250$
Five kettles out = 5×4 ($A/36000$)	$A/1800$
Six kettles out = 6×4 ($A/36000$)	$A/1500$

or $A/9000$ if only one kettle was shut down (see Table 1).

Fig. 1 shows the existing steam supply line. Fig. 2 shows a simple looping of the line with an additional valve at the supply main and a single sectionalizing valve in the middle of the loop—three kettles each side. Fig. 3 differs from Fig. 2 only in the inclusion of two sectionalizing valves—two kettles between adjacent valves, and Fig. 4 has five sectionalizing valves—one kettle between adjacent valves.

Fig. 1 shows the steam piping layout for six kettles and the other sketches indicate how the department steam header might be looped and sectionalized to avoid shutting down all the kettles when maintenance work is necessary



Using a 3 in. line to illustrate the point, let's approximate the cost of improved reliability. The piping shown in Fig. 1 is required and the added cost for improvements shown in Fig. 2 might be approximately $220, including valves, butt welding flanges, pipe, welding turns, insulation, labor, etc. If the layout of Fig. 3 is preferred over that of Fig. 1, then the added cost might be about $255. Similarly, $360 might be required for the extra equipment shown in Fig. 4. If the annual rate of amortization, or write-off, is 20 per cent, the annual dollar write-off is $44 for Fig. 2, $51 for Fig. 3, and $72 for Fig. 4.

Assuming an average of one 4 hr shutdown per year (to maintain the frequently used gate valves in the lines to the kettles) it is seen that the lost production value is $A/1500$, $A/3000$, $A/4500$, and $A/9000$ for the layouts of Figs. 1 to 4 respectively. Similarly the savings in lost production value are $A/3000$, $A/2250$, and $A/1800$ for Figs. 2 to 4.

If the annual product value A is $135,000, these savings become $45, $60, and $75 respectively for Figs. 2 to 4. These values indicate a profit of $1, $9, and $3 based on the above investment costs and annual write-offs with one 4 hr shutdown per year. Table 2 contains these figures as well as the value of the savings when the product value is $90,000 and $180,000. It should be noted that procedure under Fig. 3 is the most desirable, that Fig. 4 procedure is almost as desirable (financially), and that Fig. 2 presents an attractive picture.

It is obvious that the value of the product and the size of the lines must be considered in determining the correct extent of service insurance to be added to the existing equipment. There are other factors that must be considered, too.

Table 2 has been prepared on the basis of one 4 hr outage per year. If the valves to the kettles are subject to very frequent or none too careful operation, or if they are by any chance used as regulating valves, the possibility of valve trouble is increased. Likewise, if the line carries fluids or vapors whose corrosive or erosive action is greater than that of steam, then increased valve trouble should be expected. The table is based on a 20 per cent rate of write-off. If this rate is changed, then the value of the added investment is likewise changed.

Other items that may or may not have simple dollar values are the possible loss of product, the loss of employee time, the contingent loss due to delayed orders, and the very nature of the product and plant. Any or all of these latter items may be sufficient to justify greater piping reliability.

Usually the looping of a supply line or header will permit reduction of pipe size and thereby decrease the cost of the added protection.

Each plant or department should be analyzed for requirements of output as to value, continuity of operation, cost of lost time, and other factors. With these facts in mind

Table 2—Savings Made Possible by Improving Piping Layout (A = Annual Product Value)

Fig. No.	1	2	3	4
Added Investment	$ 0	$220	$255	$360
Annual amortization, 20% rate	$ 0	$ 44	$ 51	$ 72
Cost of 4 hr shutdown to repair defective valve in line to a kettle	$A/1500$	$A/3000$	$A/4500$	$A/9000$
Savings	None	$A/3000$	$A/2250$	$A/1800$
Annual Product Value $A = \$90{,}000$				
Annual savings	None	$ 30	$ 40	$ 50
Annual excess savings over amortization	None	—$ 14	—$ 11	—$ 22
Annual Product Value $A = \$135{,}000$				
Annual savings	None	$ 45	$ 60	$ 75
Annual excess savings over amortization	None	$ 1	$ 9	$ 3
Annual Product Value $A = \$180{,}000$				
Annual savings	None	$ 60	$ 80	$100
Annual excess savings over amortization	None	$ 16	$ 29	$ 28

a few simple calculations will serve to determine the amount of operating insurance to be installed in the form of headers and sectionalizing valves.

* * *

"Tell me, Chief, how did you get the boss to authorize those three 3 in. header valves and the looping of that steam supply header?"

"Well, Gard, you got me to thinking about those header valves last month when No. 2 kettle supply valve went to the bad. I checked with the accounting department and found that we were entitled to these improvements."

"What do you mean, entitled?"

"Well, we operate 6000 hours a year with all six kettles and on average market prices they tell me that our department has a product value of $225,000 per year. A four hour shutdown is worth $150 in product alone. If we can cut this to $50 by cutting the header into three pieces with a supply at each end, we have made a big saving."

"O.K. so far, Chief."

"Well, these valves and the pipe, fittings, and labor cost about $255. The accountants say 20 per cent of that is charged off each year, or $51. If we have only one shutdown a year we have lost $50 instead of $150 in product value and it costs us $51 for investment—$101 as against $150, or a profit of $49 per year. Better yet, we get the orders out on time because only two kettles are down instead of all six, and all the boys are not idle those four hours."

"That gets it, Chief, and I'll say this—I still know you can't operate those kettle valves the way we do without trouble once in awhile, but with the new header I can sure keep the outage time down."

Control Essential to Efficient Textile Mill Heating

By Henry F. Perkins*

VISITORS interested in or familiar with industrial plant heating invariably ask why our heating coils are on the ceiling. There are two principal reasons for this practice. The saving in floor space gained by not having these coils along the wall under the windows is one; this might not seem important at first glance due to the few inches that such coils extend from the wall, but it is quite possible to lose an entire row of machines in a wall span in a textile mill by lacking just those few inches for the alleys required between the machines.

The more important reason, however, is safety. Textile mills—especially cotton plants—are highly flammable. Floors after years of use are oil soaked and oily cleaning cloths and waste are always about. In spite of precautions and regulations, the space behind a low heating coil is a tempting receptacle for such waste. This resulted many years ago in our abandoning the more efficient heating coil location below the windows for the overhead position. (Of course, all heating is not done by coils. Blower systems are in common use, as are unit heaters. There are also places such as inspecting rooms where low coils are imperative for the comfort of the operatives who work along and close to the windows. But, for the general run of factory heating, by steam or hot water, the ceiling location is standard with us).

I have dwelt at some length on ceiling coils purposely to bring out the importance of automatic control. The amount of heat required to maintain a proper temperature is governed by the occupancy of the particular room. The horsepower used to drive the machinery is eventually dissipated as heat—which may be sufficient for heating the room during working hours for most of the winter. On exceptionally cold days and after working hours the heating valves must be opened, since a fairly uniform temperature should be maintained constantly in the manufacturing departments.

Here's the rub! The valves have been opened. There are no moving belts or operating machines to help circulate the air. The coils are up overhead so that little direct heat is felt from them. There is no one around until the watchman passes through and unless the temperature is almost unbearable nothing is likely to be done about it. If the control valve is overhead and hard to get at, still more chance that it will be left alone. After an exceptionally cold week-end control valves are left open until the machinery becomes warmed up. Here again they are easily forgotten until the temperature has reached a point where some one is reminded that it is too hot and then the valve is closed.

Automatic control valves, properly installed, will obviously solve this problem. They are not expensive for such service and the savings in steam will pay for them many times over. Another consideration involving automatic control of the heating and of vital importance to the textile industry is the necessity of uniform humidity throughout practically all of the manufacturing processes. If the temperature is not controlled it is still possible to obtain the required amount of moisture. With this variable removed, however, much better efficiency will be obtained in both the heating and moistening systems.

Automatic control of the heating in textile mills, is therefore, an essential.

*Engineer in Charge of Mechanical Research, Worsted Div., Pacific Mills.

In-Service Training Program Is of Benefit to School Engineers

By John Howatt*

AMERICANS are convention minded. Industries and professions have adopted the convention as a necessary part of business and professional life. We find conventions of doctors, of chemists, of the metal trades, of bedding manufacturers and so on ad infinitum. Why do all these groups find conventions desirable? They find them worthwhile because they enable exchange of ideas, discussion of problems, study of new methods, keeping up with the ever-moving procession of events and changes—avoiding stagnation. One cannot live in the yesterdays. The ideas and methods of 100 or 10 years ago are not necessarily true and acceptable today. The organization that does not keep itself alive and cognizant of the affairs about it that affect its own well-being will very soon become of no importance and ultimately will cease to exist. The professions and industries have long recognized this in the support of research. They recognize the need of constantly improving their old products and developing new ones to meet new demands. Millions of dollars have been spent by them in research as investments in the future.

What the different professions and industries have known and practiced is becoming more and more recognized by different governmental bodies through establishment of in-service training classes for employee groups.

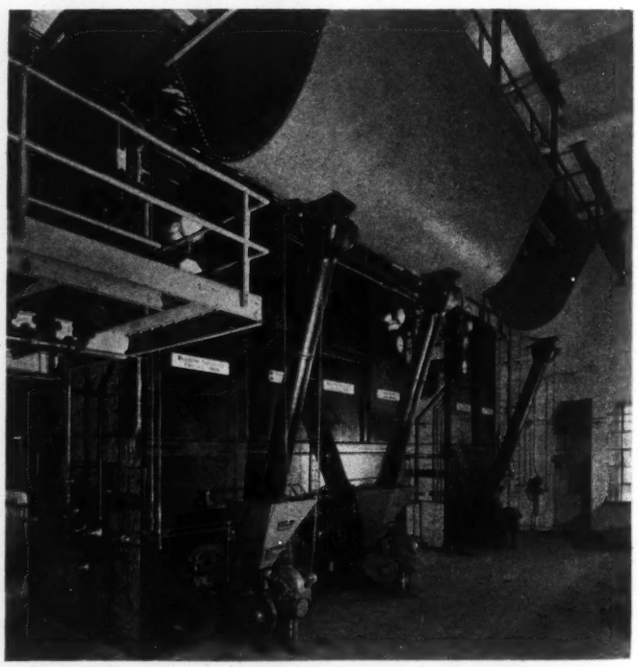
Chicago is one of the major cities where the value of in-service classes for the employees of the board of education has been recognized and action taken in the establishment of classes both for the teaching staff and for plant operation employees.

In the Chicago school system there are more than 400 separate buildings designed and constructed (some each year) since 1859 up to the present. As a consequence there is a wide variety of types of mechanical and electrical equipment, kinds and types of floor and wall surfaces, etc., that must be maintained and operated. The buildings erected in the past 20 years have had incorporated in their construction many more complex electrical and mechanical appliances than those built in the years before. What with public address systems, radio connections, automatic fire alarm systems, electrical program clocks, automatic controls of heat, humidity and air motion, air conditioning, refrigeration for cafeterias and lunch rooms, to say nothing of the water sterilization problems that must be handled in operating 40 swimming pools, the engineer-custodians in the system today must know a great deal about many things unheard of in schools built two decades ago. And with a maintenance and operating staff of 2600 there must of necessity be a wide variety in the capacity, energy and experience of the operation personnel.

The division of the city into seven districts with a supervising engineer and an inspector in each helps to standardize methods of maintenance and operation in similar types of buildings and serves to improve the quality of service through constant inspection and check. However, the supervisors and inspectors can spare sufficient time from their duties in connection with new building construction to visit each building on an average of only once a month, so the burden of providing adequate, efficient operation and maintenance must lie with the individual staff of each school building. In order that the operating engineers in the Chicago school system would each one be given an opportunity to be made conversant with the many changes taking place in the field of school equipment, and in the methods of operation and application, as well as changes in the demands of what is desired and expected, in-service training classes for this group of employees have been established.

Government employment lacks the stimulation that is provided by competition in commercial and industrial establishments. Because of that lack of stimulation, it is always more difficult to keep government employees above an average level, alive and interested in their work. Difficult to avoid stagnation is a charge that is often made against civil service employees. It has been the writer's experience that civil service employees in government work can be just as efficient, just as effective, just as alert as they are in industry if and when they are able

Boiler room of the new Gage Park high school in Chicago. A test of this plant showed an efficiency of 77 per cent



*Chief Engineer, Board of Education, City of Chicago. Member of Board of Consulting and Contributing Editors.

to maintain an interest in their work. Interest is the spark-plug that provides the stimulation in government work as well as in every other class of employment.

In-service training classes are now conducted by the Chicago board of education, with the coöperation of the engineers' organization, throughout the six winter months of the year. Meetings are held two evenings per month in a central hall donated by the board. A tentative program for the season is set up in autumn and as much of the ground as possible is covered in the season. Sessions are three hours long and provide one or two lectures an evening on some one particular phase of interest to the school plant superintendent, with a question and answer period following the lecture that proves very valuable.

The duties of a school engineer-custodian are generally classified in three divisions:

1) Those that have to do with the care and operation of heating, ventilating and other service installations.

2) Those that have to do with the housekeeping—the care and maintenance of the building from the standpoint of cleanliness and sanitation.

3) Those that have to do with the relationships of the engineer-custodian to the school principal, teachers, pupils and the public.

A program for in-service training for those engaged in school plant and building operation and maintenance should, therefore, be so planned as to include lectures and explanations on problems in all three divisions of the work. The program for 1939-1940 is as follows:

Program for In-Service Training Classes

1) Outline of the purposes, objectives and scope of in-service training with a brief summary of the subjects to be covered and the particular speakers on each subject.

2) Swimming pools: The design, care, management and operation of the pools and all necessary equipment. Explanation of the methods of maintaining sterile water, the use of germicidal agents and the proper daily check for sanitation, and explanation of records to be maintained.

3) Factors determining the design of mechanical equipment in schools with explanations of how the design load determinations are computed.

4) Explanation of the factors that determine the general design, construction, size and location of new school buildings and additions with stress on precautions against endangering health, safety or life.

5) Combustion of fuels: Studies of furnace designs, construction, types and methods of firing coal or oil as fuel with recommendations on the best methods of operating and maintaining the plants for efficient, smokeless, economical combustion. Discussion of different types of stokers, and oil burners.

6) Boilers: Discussions and illustrations of different types of boilers and boiler settings applicable to and used in school work. Special consideration of the most efficient method of operation and maintenance of the different boilers with special attention to specific features.

7) Explanations and discussions on the care and management of school buildings proper covering the various materials used in the school building and the most advisable methods for care and management of employees.

8) Relations of the engineer-custodian to different divisions of the school system with brief explanations of the overlapping duties and responsibilities of the different divisions: principal, teachers, pupils.

9) Explanations of the engineer-custodian's relationships and business requirements in the daily contacts necessary with the board of education law department, payroll division, supply division, bureau of purchases, repair division, bureau of architecture, engineering, etc., with a speaker from each division covering the detailed procedure.

10) Fire prevention and control: Safety requirements and control.

11) Plumbing: Explanation of the various types of plumbing systems used in school buildings, explanation of different city ordinances with which an engineer should be familiar, and explanation of ordinary acceptable methods of maintenance of plumbing facilities.

12) Heating and ventilating in school buildings from the standpoint of health and sanitation with a speaker from the board of health and a speaker from the American Society of Heating and Ventilating Engineers.

13) Heating and ventilating equipment: Explanations of different acceptable methods of heating and ventilating school buildings with discussions of the different appliances on the market for meeting school heating and ventilating conditions.

14) Temperature control: An explanation of the advantage of accurate temperature and humidity control in school work; discussions and descriptions of the different appliances on the market for this purpose and their application to meet air distribution, humidification and air cleaning requirements.

15) Electrical systems: Description of the electrical installations as applied to modern school buildings. Explanations of the best methods of operating and maintaining school electrical equipment.

16) Electrical systems and equipment: Explanation of city codes and ordinances applicable to the electrical industry and explanation of the reasons back of the design of different parts of electrical installations in schools.

17) Custodial commodities and equipment: Explanations by representatives from various manufacturing concerns on the purposes and usage of their particular commodities and equipment.

18) Landscaping: A lecture on planting and care of school lawns, shrubbery, trees and flowers.

19) Care of school buildings, grounds and equipment throughout the non-occupancy periods, such as Christmas vacation periods and the months of July and August.

Attendance at in-service training classes is optional, but the interest aroused has been so general the hall is filled to capacity each evening and it is felt worthwhile benefits are derived by those who take advantage of this opportunity for practical education. It is noted that the engineers who attend the in-service training classes pick up something of value at each meeting which they can apply to their own particular plants.

The USA has for years been convention minded—members of both industries and professions have adopted the convention as a part of their business and professional lives, for it enables the individual to exchange ideas, discuss new problems, learn of new methods, keep up with the ever-changing procession of events; in other words, to avoid stagnation. What the different industries and professions have long known and practiced is becoming more and more recognized and acted upon by different governmental bodies through establishment of "in-service" training classes for various employee groups. The Chicago board of education, for example, has established such classes both for its teaching staff and its plant operation employees. Mr. Howatt describes the why's and wherefore's of the latter phase of the program here

Alka-Seltzer's Air Conditioning Engineer Tells How to Avoid "Head-Aches" by Proper

Maintenance of Plant Air Conditioning

By W. E. Lowell*

AN air conditioning system usually represents a considerable investment. It was installed probably because the owner determined that he would get more out of it than its initial cost and upkeep expense. If the system was installed primarily for comfort, the return was based on the increased efficiency of the employees. If it was installed to meet the demands of a manufacturing process, the return was calculated on the basis of uniformity of product, and consistent and continuous operation. The owner is therefore concerned about the protection of his air conditioning investment and is desirous of an uninterrupted return from it. Thus, it is necessary to keep the equipment in good repair and functioning as the designer intended it should.

Suppose we start at the outside air connection and follow the air through the system to the most remote outlet, noting as we go those things that require the attention of the operating and maintenance force.

The first thing encountered is the weather louver and bird screen, often situated in a somewhat inaccessible place, such as the side wall of a building, and frequently forgotten. The result of neglect is that the protective coating disappears and the whole assembly is attacked by the elements. The bird screen rusts out, thus permitting pieces of paper and other substances to be drawn in, impinging on the preheater. This retards the inflow of outside air and upsets the balance between it and the recirculated air. This part of the system should be kept well painted with weatherproof paint.

Next we come to the preheating coils. If not preceded by filters, they will collect a vast amount of atmospheric debris in a very short time; this accumulation will bake onto the coils and affect their rate of heat transfer. These coils are also liable to damage by freezing, generally caused by improper draining. If it is not possible to place filters ahead of the preheating coils, they should be made readily accessible for cleaning and should be checked frequently for drainage.

We next pass on to the regulating dampers for recirculated, outside and bypassed air. Lack of proper lubrication may be the cause of damage to the damper motors. Rusty pivots and sprung blades will impose a burden on connecting rods, thereby altering their stroke and creating partial opening and closing. Regulating damper mechanisms should be frequently lubricated and examined for freedom of action.

The air filtering equipment is often neglected, resulting in decreased flow of air. The designer of the system calculated a definite flow of air through the filters with an allowance for a reasonable amount of dust impregnation. The frequency of cleaning or replacements is a matter of individual judgment. In some instances instruments are used to determine resistance and when a certain point is reached the filters are cleaned or discarded.

We proceed to the spray chamber. Housed in it are water atomizing nozzles, cooling coils, water heating coils, eliminator plates, and strainers around the overflow and suction pipes.

The nozzles are subject to clogging unless they are of the self cleaning type. Each nozzle is designed to handle a definite amount of water under certain pressures, but if the orifice is plugged the quantity of water is reduced and the mist is insufficiently divided.

If the cooling coils are supplied with a refrigerant and are under float control they frequently accumulate considerable oil and non-condensable gases, both of which reduce their cooling effect.

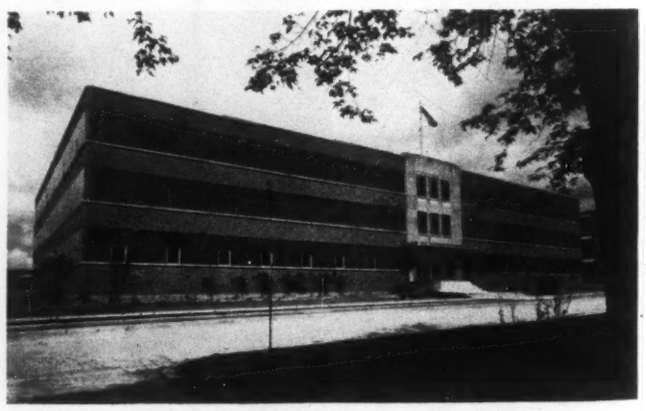
Where well water is circulated through the coils as a cooling medium, the presence of algae has often been noted in goodly amounts, together with other sediment. This, of course, affects the heat transfer. The water heating coil for winter humidification requires little or no attention, as a rule.

Entrained moisture may be carried in the air stream beyond the eliminator plates; generally, this is due to the air velocity being too high or too low. The angle of deflection, number of bends and hooks, etc., is usually worked out very accurately by the designer. However, local adjustments (such as increasing or decreasing the volume of air, or using brine in a unit designed for water) may cause moisture to carry through.

The spray chamber itself should be watched for evidences of corrosion. It should be frequently painted on the inside. Access doors must be kept air tight.

Refrigerating coils should be purged of oil and air at periodic intervals. Frequent doses of chlorine or other treatment will keep water cooling coils free from algae growth.

New air conditioned plant of the Miles Laboratories, Elkhart, Ind., of brick and glass block construction



*Air Conditioning Engineer, Miles Laboratories, Inc.

Strainers at overflow and suction pipes should have frequent inspections.

Despite the efficacy of the filters and precautions against air leakage on the suction side of the fan, a certain amount of dust is pulled through and impinged on the fan blades. Any appreciable accumulation of this kind decreases the air delivery and may throw the wheel out of balance. Then, too, the inside bearing on the fan often escapes attention. Normally, a fan will run for many years without requiring much attention other than lubricating and cleaning. However, leakages do occur around housings which can readily be remedied by caulking.

The distributing and return ducts were designed to produce definite results at certain areas. The conditions can be affected by altering positions of slice dampers and outlet registers. Leakages manifest themselves by discoloration. Some areas may be starved because of an over-abundance of air at other points or by reason of subsequent additional branches being inserted into trunk ducts. The whole air conditioning system may appear faulty if there is improper distribution of the air and minus pressures within the conditioned space.

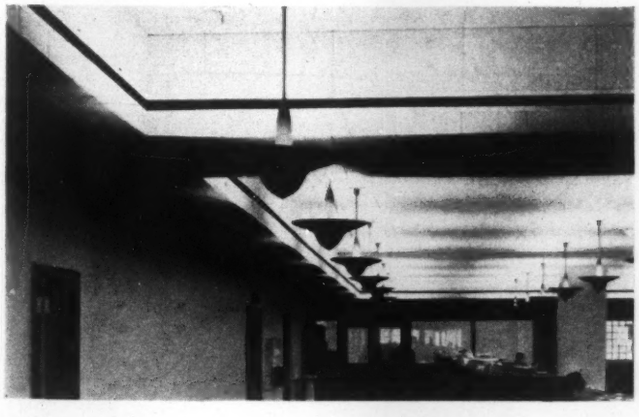
Undoubtedly, the amount of air out of each outlet was determined with an anemometer when the system was first placed in operation. A check now and then with such an instrument to keep the system in balance is advisable. The outside air should be regulated to maintain a plus pressure within the conditioned spaces; this prevents infiltration. Any air entering the room other than through the distributing ducts must be conditioned by the room itself rather than by the air conditioning unit.

This is an important point because at times complaints have been registered about rooms not being properly conditioned, and investigation revealed the faulty conditions only around doors and other openings. A change from a minus to a plus pressure corrected the fault.

Thermostats and other controls are placed on columns, walls and partitions and as a rule forgotten other than for an occasional adjustment to raise or lower temperatures and humidities. Weekly examinations of this equipment should be made. Contact points should be cleaned and bellows examined for leaks and corrosion.

A well is essentially but a hole in the ground, but it should not be neglected. A check with a recording ampere meter on the motor driving the pump might reveal

A view of the general office area. Air is introduced through continuous narrow slots in the shallow ducts



Mr. Lowell outlines briefly the importance of proper maintenance of air conditioning systems in industrial plants, based on his extensive experience in this work. . . . An owner usually invests in air conditioning because he will get more out of it than he must put into it; proper maintenance is important in protecting his investment

only partial delivery of water. With two or more wells tied into the system, one pump could be pulling in large quantities of air over a long period without being observed. This might be due to too great a drawdown exposing part of the screen. After a period of hard use it sometimes becomes necessary to re-develop the wells and clean the screens.

Air Conditioning for Alka-Seltzer

At the Miles Laboratories we have two separate air conditioning systems—one for comfort and the other for process in connection with the manufacture of Alka-Seltzer and other products. The building walls are of brick and glass block construction sealed against outside air infiltration. This construction facilitates control of the temperature and humidity.

Well water is used as a cooling medium during the warm seasons and steam supplies heating during the colder periods. Each floor carries two air conditioning units with duct work. They are situated at opposite ends of the building, thus eliminating the use of large trunk ducts. The ducts are wide and shallow, fitted tight against the ceiling. The openings are small and on close centers. The duct work in the general office carries a continuous narrow slot on each side for air distribution, instead of the conventional grilles.

The complete exclusion of outside air infiltration has made it possible to operate with a very close temperature differential between the room and the air leaving the air conditioners. The control is central and not zoned. Total capacity of the comfort air conditioning equipment is 90,000 cfm—using approximately 600 gpm of 51 F well water. As the well water will not produce a dew point low enough for process, we use refrigeration.

Capacity of the ammonia compressor equipment is 200 tons. The process air conditioning system handles a total of 40,000 cfm.

All of our roofs are dead level and designed to carry 4 in. of water to reduce heat gains through them. A large portion of the water from the air conditioning units is shunted to the roof and from there it flows to the sewer.

Temperatures and humidities are checked and recorded each hour of the day, and the entire system is under the control and supervision of six people. Very definite periods are set for certain functions, such as changing filters, purging and cleaning, and the dates are recorded. Flow meters are placed in the lines supplying water to air conditioners from time to time to determine quantities. Motors are frequently tested for overloads.

Constant supervision and vigilance of this kind keeps the system functioning properly. When it does, it is a source of profit which repays to the owner his investment in air conditioning.

Standardization of Pipe Welding Bevels

I HAVE read with interest the article on How to Weld Heavy Wall Pipe with the Single Flame, Multi-Layer Technique, by M. R. Scott, on pp. 623-626 and 628 of the October, 1939, HPAC. It is helpful to know that progress in multi-layer technique, which has been so successful in the application of arc welding to heavy walled material, is being made.

May I point out, however, one feature of the article which tends to promote confusion among those concerned with the preparation and welding of pipe joints? The use of a welding bevel having an included angle of 50 to 60 deg is advocated. Without questioning the ability to weld successfully to this rather narrow angle, may I point out in the interest of standardization that it is contrary to recommended practice of the American Standards Association. The recommended bevel for wall thicknesses of $\frac{3}{16}$ to $\frac{3}{4}$ in. is 37½ deg ± 2½ deg, giving an included angle of 75 deg.

This recommended practice was adopted by ASA sectional committee B16 some two years ago in the interest of uniformity. Much more is involved than just the field beveling of pipe ends, since trade practice calls for manufacturing and stocking pipe, ready made welding fittings, and welding neck flanges to a generally recognized standard which is acceptable to all.

At one time the industry was well started toward accepting the 45 deg bevel (90 deg included angle) as standard, but this gave way to the 37½ deg bevel to suit the preference of the petroleum industry. Committee B16 adopted the 37½ deg bevel as recommended practice some two years ago on the advice of a working subcommittee which carefully considered various conflicting suggestions for bevels ranging all the way from 20 to 45 deg (40 to 90 deg included angle) and in some cases varying to suit small changes in wall thickness. It was the conclusion of the committee that these distinctions had little significance, since good work could be done with little difference in cost for most any of the bevels proposed using the proper combination of bevel angle and root spacing. Owing to the American Petroleum Institute's 37½ deg bevel being well established in the oil industry, which represented a large volume of business, it was unanimously decided to adopt 37½ deg as recommended practice for wall thicknesses of $\frac{3}{16}$ to $\frac{3}{4}$ in. for both gas and electric arc welding. Since this action by sectional committee B16, the 37½ deg bevel has been adopted as standard by the manufacturers of ready made butt welding fittings and is generally accepted throughout the piping trade.

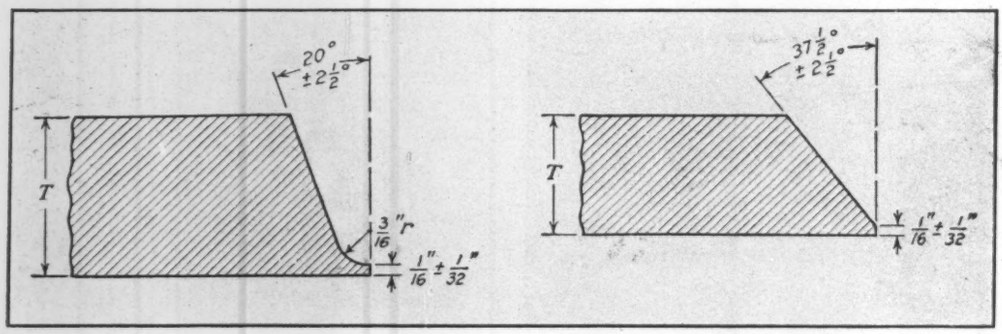
Subgroup 6 of committee B16 has recently completed formulating a proposed American Standard for Butt Welding Fittings. For the reasons stated above, it has incorporated in this proposed standard requirements for beveling the ends of butt welding fittings which are identical with the recommended practice of ASA B 16e-1939.—SABIN CROCKER.*

REPLY BY M. R. SCOTT†—We are in complete accord with the ASA in their efforts to standardize on the type of bevel to be used for fusion pipe welding. For purposes of standardization at the present time, furthermore, we agree that a 37½ deg bevel is satisfactory for gas welding of pipe wall thicknesses between $\frac{3}{16}$ and $\frac{3}{4}$ in. On the other hand, industry is naturally interested in effecting economies wherever this can be done without sacrificing quality. It is obvious furthermore that any reduction in the angle of bevel will result in a reduction in cost of making the weld due to the smaller amount of weld metal required to fill the joint.

My article covered the results of recent investigations which indicate that with oxy-acetylene welding employing the multi-layer technique, economy is effected with no sacrifice in quality by the reduction of the bevel angle below 37½ deg. We can see no reason, therefore, why this smaller angle of bevel should not be recommended where the recommended angle can be readily obtainable. There can be no question, furthermore, that where a 37½ deg bevel is employed, an equivalent quality will be obtained at the sacrifice of some economy in the welding.

*Chairman, Subgroup 6 on Welding Fittings, ASA Sectional Committee B16. Senior Engineer, Engineering Div., The Detroit Edison Co. Member of Board of Consulting and Contributing Editors.
†Service Engineer, The Linde Air Products Co.

***Left*—Standard U bevel of welding ends for thickness *T* greater than ¾ in. This form of bevel is not recommended for acetylene welding and may be changed to the straight bevel shown at the right. *Right*—Standard straight bevel of welding ends for thicknesses *T* $\frac{3}{16}$ in. to ¾ in., inclusive (From American Standard Steel Pipe Flanges and Flanged Fittings, ASA B16e-1939)**



Regulating Condenser Water for Refrigeration Systems

By Alwin B. Newton*

IN refrigeration systems using city or well water for cooling condensers, it is important that proper means be employed for controlling the amount of water passing through the condenser so that it will be sufficient to maintain a desirable head pressure and at the same time will not waste water. Of the various means commonly employed, it may be that only one will be suitable for the peculiarities of any particular installation. To assist in selection, this analysis sets forth the characteristics of different pressure control methods.

Factors Affecting Selection

The control requirements vary with the type of compression equipment. For example, with a reciprocating compressor, economy of the system as a whole in use of power and water is usually of prime importance, although in some cases it is necessary to sacrifice some economy either to maintain a relatively low head pressure to prevent overloading of the compressor motor or for other reasons. With centrifugal compression equipment the problem is different; perhaps the factor of prime importance here is to maintain a low enough head pressure to insure proper compression, since with centrifugal equipment, if the head pressure is allowed to go too high, all refrigerating effect may be lost. By the choice of a proper condenser water control system either of these characteristics can be properly provided.

Of practical importance is the reaction of the control system to abnormal conditions, such as the accumulation of dirt in the condenser tubes, lack of water supply, air in the system, and abnormally high or low inlet water temperature. The degree of liquid subcooling is important with some refrigerants. It is usually desirable to prevent wastage of condenser water in case of loss of refrigerant charge. Some installations require discharge pressure above a definite minimum to insure proper refrigerant circulation.

Pressure Control

A direct acting pressure control valve (Fig. 1) or a motorized valve controlled by a pressure responsive device (Fig. 2) may be employed to regulate the flow of condenser water. The valve is arranged so that upon a rise in head pressure the valve opens to increase the flow of water. In this way the tendency is to keep the head pressure substantially constant.

The pressure control system is simple, maintains substantially constant discharge pressure under most load conditions, and gives desirable liquid temperatures leaving the condenser. The pressure limitation feature is valuable in centrifugal machine work where it is necessary to prevent excessive head pressures to maintain refrigeration capacity. However, the refrigerants employed in centrifugal work often operate at extremely low pressures or in the vacuum range, and hence valves operated directly by pressure may be difficult to obtain. In these cases a pressure control actuating a motorized valve is found useful, as in Fig. 2.

Pressure control usually reacts as follows to changing conditions within the system:

Effect of Dirty Condenser—A gradual accumulation of dirt or scale in the condenser is at first accompanied by a slight increase in the water flow and in the discharge pressure. Continued dirt accumulation will eventually cause a loss of heat transfer capacity, so that the water valve will go to the wide open position during operation of the compressor. Such a condition indicates itself to the operating engineer by an unwarranted increase in the flow of condenser water, and may even serve as an indicator of dirt accumulation within the condenser. In extreme cases it will also be indicated by an abnormal rise in the discharge pressure.

Lack of Water—In case of temporary reduction in water pressure, the discharge pressure will rise slightly, causing the water control valve to open. If, when the valve is opened wide, the supply of water is not sufficient to maintain the desired head pressure, a continued rise in the discharge pressure will be experienced, the amount depending on the available water supply. Of course, opening the valve is all that any control system can do under these conditions.

Effect of Air in Condenser—Whenever air leaks into a refrigeration system, or is left in it when it is put into operation, the total pressure will be higher than the condensing pressure of the refrigerant. Only slight rise in head pressure will normally occur under these conditions, causing the control valve to open more widely. This action is particularly desirable on systems where it is important to maintain a definite head pressure, such as with centrifugal machines. However, the amount of water which will be used under these conditions is in excess of that required in an air-free system, and if sufficient air accumulates, the head pressure cannot be maintained even with the valve wide open. The length of time the pressure valve remains open after the compressor is shut off is usually a good indication of the accumulation of air in the system. An unduly long period with the valve remaining open indicates the system should be purged.

Liquid Temperature—The liquid temperature depends upon the amount of charge in the condenser, and the proximity of the

Of the various means commonly employed for controlling the cooling water for refrigeration condensers, it may be that only one will be suitable for the peculiarities of a specific installation. To assist in proper selection, this analysis sets forth the operating characteristics of different pressure control methods. The effects produced by some of the abnormal conditions which occur from time to time during operation are pointed out, and how the controls react to them is explained by the author

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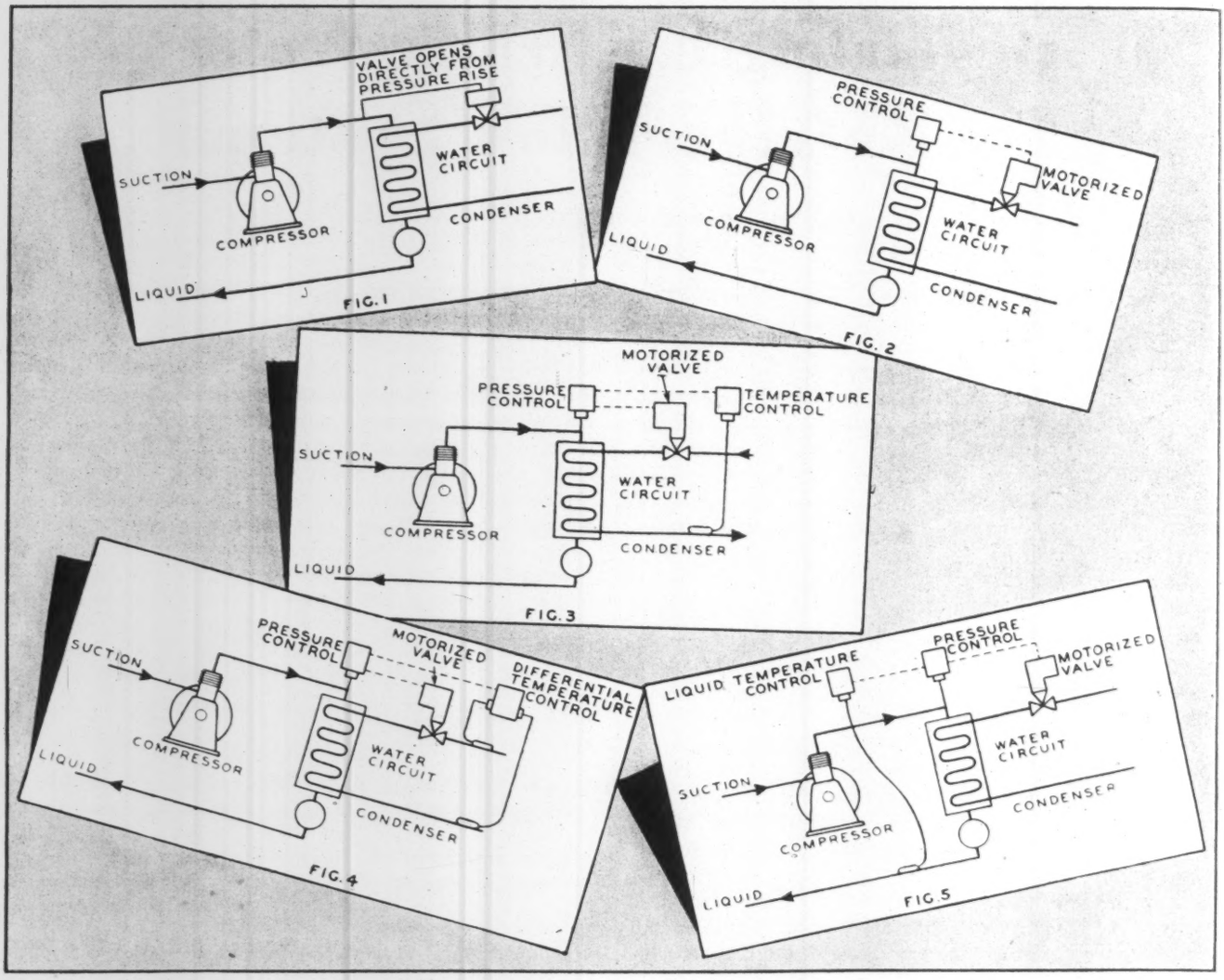


The operation of the methods of condenser water control diagrammed here is analyzed in the text

heat transfer surfaces to the liquid. The tendency is to give a fairly constant degree of liquid subcooling as the load varies, although quite often a tendency exists to give increased subcooling at light loads as compared to that obtained at heavy loads.

High Inlet Water Temperature—In the event of high inlet water temperature, pressure control increases the water flow in attempting to maintain a definite head pressure. The pressure should not go out of control as long as the heat transfer characteristics of the condenser permit adequate control of the head pressure at the existing water temperature. Thus, capacity of the system is normally maintained as long as it is physically possible for heat to be transferred.

Low Inlet Water Temperature—Low water temperatures are experienced during the entire season in some localities, while during only the spring and fall months in other localities. With pressure control an adequate flow of water is maintained so that the head pressure will assume the desired value, regardless of how low the inlet water temperature may go.

As the water flow is decreased, the velocity becomes less through the condenser tubes, causing a reduction in the heat transfer rate. With some systems of control it is possible to reduce the water flow to such an extent that streamline rather than turbulent flow characteristics are obtained. This difficulty is eliminated with pressure control, since sufficient water flow to maintain the head pressure is automatically maintained, and this almost invariably means sufficient flow to put it in the turbulent region.

Loss of Charge—Loss of the refrigerant charge, if it occurs gradually, will be accompanied by a decrease in the amount of refrigerant circulated. As long as sufficient refrigerant is in the system to build up the head pressure to the control point, a constant head pressure will be obtained. Continued loss of charge to the point where the discharge pressure does not rise to open the pressure operated water valve allows it to remain closed and no water wastage will occur.

Starting Conditions—Pressure control automatically starts the water flow as soon as the compressor has operated sufficiently to build up a desired head pressure.

Requirements for Constant Discharge Pressure—In many cases, due to the elevation of cooling coils above the condensing unit or to the expansion valve size, it is necessary to maintain sufficient head pressure to insure circulation of refrigerant. This is automatically taken care of with pressure control systems and, in fact, the pressure may be readjusted easily, if it is discovered after the installation of a system that sufficient head pressure does not exist to give proper operation. Even at exceedingly low ambient or water supply temperature the pressure control still insures a minimum pressure which is satisfactory to the particular system.

Pressure Control Compensated by Water Temperature

Some of the advantages of pressure and temperature control may be combined in a compensated system. The arrangement is usually employed where further economy

in the use of condenser water is desired, and where at the same time it is important to maintain the head pressure within desirable limits. Economy is accomplished by allowing the discharge pressure to vary within predetermined limits, so that when a higher water temperature is experienced, a higher head pressure gives economy in water usage. The temperature control may respond to either inlet or discharge water, but normally responds to the latter.

The control is arranged so that the pressure control acts as the main controller and limits the pressure variations to a fairly wide but definite range. The particular portion of this range which is used is varied according to the water temperature, so that the maximum economy will be secured. Fig. 3 shows a typical arrangement.

Effect of Dirty Condenser—As dirt accumulates in the condenser, increased water flow is required to prevent undue rise in discharge pressure. The pressure control provides this action as long as sufficient heat transfer capacity exists, in a manner similar to the plain pressure control.

Lack of Water—In the case of lack of water, the valve will go to the open position and the lowest attainable head pressure will be reached.

Effect of Air in System—Air in the system will tend to cause an increased head pressure which moves the valve to a more open position, thus maintaining full capacity as long as possible.

Liquid Temperature—Liquid temperature again depends on the heat transfer characteristics of the condenser, but in general a fairly constant degree of liquid subcooling will be obtained.

High Inlet Water Temperature—High inlet water temperature will tend to cause an increase in the discharge water temperature and a constant rise in the control point of the pressure controller. The pressure rise is limited by the action of the pressure control so that in general an undesirably high pressure will not be reached.

Low Water Temperature—At low water temperatures there is a tendency for the leaving water temperature to be lowered so that a lower head pressure will be obtained. The reduction in head pressure is limited to a reasonable economic value by the action of the pressure control.

Loss of Charge—Since the pressure control is the controller in this system, a loss of charge causes approximately the same reaction as obtained by simple pressure control.

Starting Conditions—The pressure control is always able to open the valve and hence when the compressor is first started the rise in pressure opens the valve before a rise in leaving water temperature is experienced. As soon as water flow is established, the temperature control begins to function and thus no extra equipment is required to initiate the water flow.

Requirements for Minimum Discharge Pressure—The minimum discharge pressure will be limited to the lowest pressure at which the pressure controller will respond. Therefore, by proper choice of the pressure control adjustment, a definite minimum satisfactory for the system may be assured.

Pressure Control Compensated by Differential Temperature

Some advantages of the pressure controlled and the differential temperature controlled system are obtained by combining them. Economy is often improved by allowing a higher discharge pressure, as the differential tends to increase. Fig. 4 shows a typical layout.

Effect of Dirty Condenser—Since pressure control is involved in this system, substantially constant head pressure will be maintained as long as possible whenever the condenser starts to become dirty.

Lack of Water—A lack of water will cause an increase in both the differential temperature and the pressure so that the water valve will be moved to an open position.

Effect of Air in the System—Air in the system tends to cause a slight increase in discharge pressure so that the pressure control will position the valve to maintain a substantially constant pressure as long as sufficient heat transfer capacity exists. The increased water flow which results decreases the rise in water temperature as it flows through the condenser, and thus resets the pressure control to call for a lower discharge pressure. Thus, full valve opening is reached more quickly than with a plain pressure controlled system.

Liquid Temperature—The liquid temperature depends to a great extent upon the heat transfer characteristics of the condensing system, but a general tendency will exist for an increase in the amount of liquid subcooling as the load on the system decreases.

High Inlet Water Temperature—When inlet water temperature rises, less water temperature rise is available at any given head pressure, and there is usually a tendency toward reduction in head pressure as water temperature rises. This may waste water unduly.

Low Inlet Water Temperature—Low inlet water temperature increases the available temperature rise and allows an increase in head pressure. This action economizes on water, and is one of the features of this method.

Loss of Charge—In case of loss of charge a head pressure at least sufficient to circulate refrigerant will be maintained by the action of the pressure control.

Starting Conditions—Since the pressure control can always open the valve by itself, no additional equipment is required to start the water flow at the time the compressor starts.

Requirements for Minimum Discharge Pressure—The minimum discharge pressure will be limited to the lowest pressure at which the pressure controller will respond. Therefore, by proper choice of the pressure control adjustment, a definite minimum satisfactory for the system may be assured.

Pressure Control Compensated by Liquid Temperature

With certain refrigerants, the liquid temperature bears an important relationship to capacity. When this condition exists pressure control may be compensated by liquid temperature so as to maintain a more uniform heat content in the liquid refrigerant.

The pressure control is normally the controlling device and is compensated by a liquid temperature controller. The controls are so arranged that a rise in liquid temperature calls for a decrease in the control point of the pressure controller. It is the usual practice to use a pressure control and temperature control which coöperate in the control of a motorized valve, Fig. 5.

By reducing the head pressure when an increase in liquid temperature occurs, the effect is to produce a substantially constant liquid temperature, as long as the water temperature and supply conditions permit. This will cause an increased flow of water under any conditions, such as heavy load, which might tend to raise the liquid temperature. Therefore, the system should be used only where liquid temperature is of paramount importance, since it is probably not as economical as the straight pressure control system.

Effect of Dirty Condenser—As dirt accumulates in the condenser the initial effect is for the pressure control to increase the water flow in an attempt to maintain constant discharge pressure. As the liquid temperature increases beyond the setting of the liquid temperature controller, this controller also acts by lowering the effective setting of the pressure control, so that

it attempts to carry a lower discharge pressure. Thus, there may be more wastage of water than with other systems.

Lack of Water—A temporary lack of water will cause both the discharge pressure and liquid temperature to rise, so that the control valve goes to the open position.

Effect of Air in Condenser—The initial effect of air in the condenser is to cause a slight increase in discharge pressure for a given load condition, so that the pressure control opens the valve more widely. Usually, due to the fact that the actual condensing temperature of the refrigerant is well below that corresponding to the discharge temperature, the liquid temperature controller will not be called into operation under this condition.

Liquid Temperature—Whenever the liquid temperature rises beyond the setting of the liquid temperature controller, it causes the pressure controller to call for a lower head pressure, thus keeping the liquid temperature below a maximum value as long as it is within the capacity of the condenser to do so.

High Inlet Water Temperature—High inlet water temperature will normally be taken care of by the slight increase in pressure which occurs to cause the valve to open more widely. In case the water temperature is high enough to cause an undue rise in liquid temperature, the liquid temperature controller enters the picture and by resetting the effective control point of the pressure control causes the valve to open wider. Under certain conditions this may cause unnecessary waste of water, but when using refrigerants with which liquid temperature is important, such wastage may be necessary.

Low Inlet Water Temperature—The pressure control reduces the water flow whenever the inlet water temperature is abnormally low and prevents the head pressure from falling to an undesirably low value. The liquid temperature control seldom comes into play under these conditions.

Loss of Refrigerant Charge—A gradual loss of charge will cause the pressure control to react to reduce the water flow and maintain the head pressure as long as there is sufficient refrigerant left in the system. The liquid temperature controller seldom is called upon to act under these conditions.

Starting Conditions—The pressure control automatically starts the flow of water as soon as the compressor has operated sufficiently to raise the head pressure.

Requirements for Constant Discharge Pressure—Since the pressure control is the controlling device and is merely compensated by the liquid temperature controller, it insures at least a minimum discharge pressure which may be chosen to insure proper circulation.

Foreign Experiences with Radiant Heating

By Stephen Zamenhof

THE following information on foreign experiences with radiant or panel heating systems was prepared by Dr. Zamenhof from the original articles published in German. Progress with this method of heating has been more rapid abroad than in this country; American interest in the principle is such that it is felt these reports should be useful—THE EDITORS.

New French System

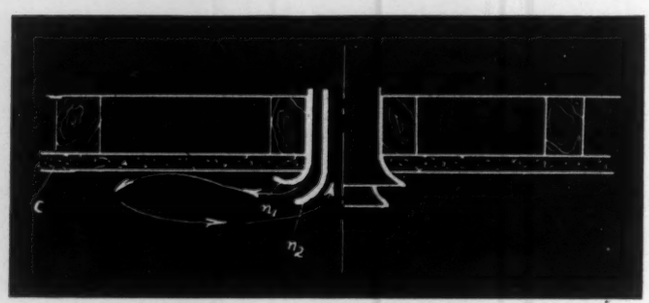
A new French system of panel heating is based on heating the ceiling not from within but by means of warm air which is introduced directly under the ceiling.[1] The warm air spreads out under the ceiling, giving its heat to the ceiling surface by direct contact. The heat is then radiated from the ceiling into the room.

As the drop of temperature between the heating agent (warm air) and the heated surface (ceiling) is much smaller than in the case of heating coils installed in the ceiling, the temperature of the heating agent may be lower. It is stated that in the case when a ceiling temperature of 86 to 140 F is desired, the temperature of the heating air may be only 18 to 54 F higher.

Referring to the sketch, the warm air, entering the room by means of nozzles n_1, does not mix with the air in the room, as in the case of an air conditioning plant, but serves to heat ceiling c only. It is then exhausted by the nozzles n_2. Of course, both nozzles may be arranged separately, in any desired manner.

[1]Radiation Heating, by P. Ritter, *Gesundheits-Ingenieur*, August, 1939, p. 513.

New French method of radiant heating



Radiant Heating in Bohemia

The first experiments in radiant heating in Bohemia were performed in 1935. After several years of constructional changes the full concrete ceiling construction (ceiling plates) was adopted.[2] This method of heating has found many applications in apartment houses.

Recently the possibility of combining the radiant heating principle with the heat pump has been investigated; in this case one can take advantage of the high natural heat accumulation in the radiant heating plant.

The cost of a radiant heating plant is reported to be 30 per cent higher than the cost of a conventional radiator plant in apartment houses and 50 per cent higher in one family houses. In hospitals this difference is lower.

Statistics indicate that in Bohemia (September, 1938) there were 23 radiant heating installations in apartment houses, nine in business houses, three in hospitals, two in one family houses and one in a school.

Danish Experiences

The author[3] investigated the ceiling panel radiant heating plant in six school rooms in Copenhagen as compared with the radiator heating plant in the six other rooms in the same school. The rooms have dimensions of 25.4 x 30.8 x 11.5 ft.

The measurements were performed under conditions

[*Concluded on p.* 102]

[2]Radiation Heating in Bohemia, by V. Skokan, *Gesundheits-Ingenieur*, July, 1939, p. 392.

[3]Danish Experiences About Heat Consumption in Panel (Ceiling) Radiation Plants, by P. Beck, *Gesundheits-Ingenieur*, April, 1939, p. 177.

Corrosion in Steam Heating Systems

Removal of Carbon Dioxide by Feedwater Treatment

By Leo F. Collins* with Everette L. Henderson†

FOUR different experimental studies have been conducted in the laboratory to determine the possibility of removing carbon dioxide (CO_2) from sodium bicarbonate solutions.

1) *Aeration with Spray Nozzles*—In these experiments zeolite-softened Detroit city water, partly neutralized with acid, from a regular plant cycle, and the same water completely neutralized, for test purposes, was passed through three different sizes of spray nozzles. Arrangement of the test apparatus is shown in Fig. 17. The effluent was allowed to fall different distances through the air, was collected under kerosene oil in a beaker, and was analyzed. The average results obtained are shown in Table 7.

Table 7—CO_2 Removed from Sodium Bicarbonate Solutions by Free Fall Aeration Using Spray Nozzles

	Influent[a]				Effluent							
	Bicarbonate (HCO_3) Ppm	Free CO_2 Ppm	Total CO_2 Ppm	pH Value	Bicarbonate (HCO_3) Ppm	Free CO_2 Ppm	Total CO_2 Ppm	pH Value	Nozzle Outlet Orifice Diam., In.	Distance, In., Water Traveled in Air	Free CO_2 Removed Ppm	Static Head on Nozzle, Lb per Sq In.
Partly Neutralized $NaHCO_3$ Solutions[b]	37	21	48	6.3	37	7	34	6.7	0.375	61	14	5
	37	22	49	6.3	37	7	34	6.7	0.500	65	15	5
	38	20	47	6.3	38	10	37	6.7	0.625	55	10	5
	40	19	48	6.3	40	9	38	6.7	0.625	68	10	5
Almost Completely Neutralized $NaHCO_3$ Solutions[b]	5	39	43	5.4	5	14	18	5.8	0.375	61	25	5
	2	49	50	4.5	2	12	13	5.5	0.375	84	37	5
	2	44	45	5.0	2	10	11	5.6	0.375	120	34	7
	5	43	46	5.4	5	18	22	5.8	0.500	65	25	5
	0	50	50	.....	0	18	18	.....	0.500	84	32	7
	2	44	45	5.0	2	21	22	5.3	0.625	68	23	5
	4	44	47	5.3	4	14	17	5.8	0.625	96	30	7

[a]Temperature substantially constant at 50 F.
[b]Detroit city water, zeolite softened.

Under these conditions maximum removal was effected when the smallest nozzle was used, when the water was almost completely neutralized and when the water fell through the greatest distance—about 120 in. It is also true that removal of *free* CO_2 reached a maximum when the water was appreciably alkaline. Under optimum conditions, however, no decomposition of sodium bicarbonate was effected nor was the *total* CO_2 reduced below 11 ppm [parts per million.]

2) *Experiments with an Acid Zeolite and Aeration*—In these experiments varying proportions of water from an acid zeolite and from a conventional sodium zeolite softener were allowed to percolate downward through five copper trays. The arrangement of the apparatus is shown in Fig. 18.

Acid zeolites have the ability to exchange hydrogen for metallic cations.** The resulting solutions, therefore, contain only acids corresponding to the concentration of bicarbonate, chloride, and sulphate in the original water. In the case of Detroit water the total chloride and sulphate (as equivalent H_2SO_4) equals about 40 ppm. By adding to this water varying amounts of sodium zeolite softened water an aerator influent containing varying bicarbonate alkalinities was produced. It was by this method that the curve in Fig. 19 was obtained. The points plotted represent the average of about four determinations. The time required for the water to pass through the aerator was judged to be about 2 min.

3) *Aeration in a Bubbling Tower*—In this experiment Detroit city water after being zeolite-softened and partly acidulated and after passing through a non-deaerating type feedwater heater, was subsequently made to flow through the bubbling tower arranged as shown in Fig. 20. Air was forced through the grid in the bottom of the tower and passed up through the water. In Table 8 is shown the analysis of the water before and after being treated with different quantities of air.

It can be seen that merely by agitating the water, as was done by passing it through the tower, some removal (2 ppm of free CO_2) was effected even when no air was added; further, that the amount of free CO_2 removed is a function of the amount of air used per unit quantity of water and that it is proportional to the velocity at which water passed through the tower; and, finally, that no decomposition of sodium bicarbonate was effected at the temperatures used.

4) *Steam Distillation Experiments*††—In these tests

††The material in this paragraph was obtained from laboratory work done by E. P. Partridge in 1925-26, working as The Detroit Edison Co. fellow in chemical engineering at the University of Michigan.

Laboratory experiments bearing upon the removal of carbon dioxide by treatment of the feedwater is the subject of this month's installment of the Collins-Henderson treatise on corrosion in steam heating systems. The arrangements for and results of four different experimental studies are reviewed and data obtained from plant equipment on the removal of gases from feedwater will be presented next month. . . . The comprehensive treatment of heating system corrosion, of which this is a part, is based upon 15 years of research work for The Detroit Edison Co. Engineers concerned with operation and maintenance of plant and building heating systems, district heating engineers, and industrial piping engineers will find the information as useful as will designers and installers of heating plants. . . . Because of its length, it is necessary to publish this material in serial form; the reader is accordingly cautioned not to pass final judgment on the data until publication of the entire article has been completed

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†Professor of Chemistry, University of Detroit.

Part 6. Part 1 was published in Heating, Piping and Air Conditioning, September, 1939, pp. 539-542; Part 2 in October, pp. 620-622; Part 3 in November, pp. 675-677; Part 4 in December, pp. 735-738; and Part 5 in January, 1940, pp. 24-27.

**Cation—a positive ion.

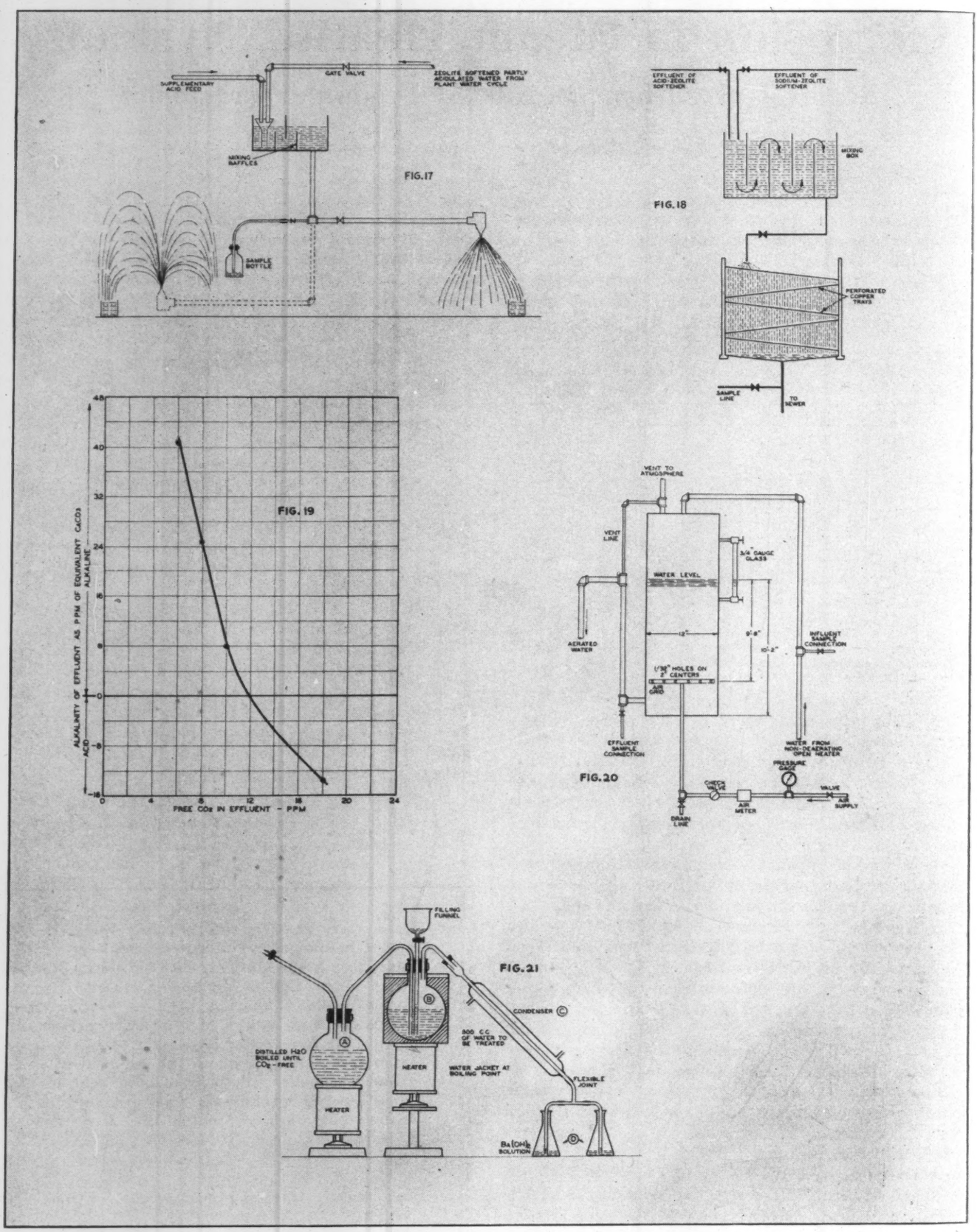


Fig. 17—Arrangement of apparatus for aeration tests using spray nozzles. . . . Fig. 18—Arrangement of apparatus in acid zeolite studies. . . . Fig. 19—Data showing the free CO_2 in water of varying degrees of neutrality after tray type aeration at room temperature; water temperature about 40 F. . . . Fig. 20—Arrangement of bubbling tower apparatus for diffused aeration studies. . . . Fig. 21—Arrangement of apparatus in steam distillation tests

Table 8—CO_2 Removed from Sodium Bicarbonate Solutions by Diffused Aeration in a Bubbling Tower

Air Used[a]	Water Treated Lb per Hr	Influent[b]			Effluent			Time of Treat. Min (Approx.)
		Bicarbonate (HCO_3) Ppm	Free CO_2 Ppm	pH Value	Bicarbonate (HCO_3) Ppm	Free CO_2 Ppm	pH Value	
0	360	32	13	6.8	32	11	6.9	79
32	880	29	18	6.6	29	3	7.4	32
96	480	28	20	6.6	28	2	7.4	59
177	395	29	18	6.6	29	1	7.4	72
230	226	28	16	6.6	28	1	7.4	125
280	360	31	19	6.6	31	1	7.5	79

[a]In cu ft per hr per 1000 lb of water treated.
[b]Detroit city water zeolite softened; temperature ranged from 154 to 180 F.

the apparatus was arranged as shown in Fig. 21. After boiling the distilled water in flask *A* to remove CO_2, steam at about atmospheric pressure was passed through the bicarbonate solutions in flask *B*. The latter was jacketed in boiling water to minimize condensation. The carbon dioxide was swept out with the steam and dissolved in the condensate formed in *C*. The cold condensate was discharged into a known amount of barium hydroxide solution in *D*. The amount of condensate discharged was obtained by weighing flask *D*. By this means the amount of gas removed by successive increments of steam was determined. The technique necessary to avoid loss of carbon dioxide and pollution from the atmosphere was somewhat involved but will not be discussed.

In Table 9 are shown the data obtained when the original solution, a partly neutralized portion, and a portion almost fully neutralized were treated.

It should be noted this technique employed all the expedients that theory indicates will hasten the reaction. The water was violently agitated (utilizing the principle of diffused aeration), was in contact with a gas phase initially free from CO_2, and was heated. These are the same basic principles employed in commercial apparatus (operating at positive pressures) for removing gases from feedwaters.

An examination of the data shows that the CO_2 in the water was reduced to less than 3 ppm only when the above named factors were supplemented by the addition of enough acid to decompose all the bicarbonate and when a quantity of steam equal to 10 per cent of the weight of the water treated was passed through the water *after* the latter had been heated to the boiling point. In brief, a quantity of steam equal in weight to 22 per cent of the weight of water tested had to be bubbled into or through the latter at such a rate as to require approximately 14 min in order to obtain the desired result.

[*To be continued*]

Table 9 — CO_2 Removed from $NaHCO_3$ Solutions by Steam Distillation[a]

	Total Steam Used[b]	Steam Bubbled Through[c]	Free CO_2 Ppm	Bicarbonate (HCO_3) Ppm	Carbonate (CO_3) Ppm	Hydrate (OH) Ppm	Residual Total CO_2 Ppm	Approx. Time of Heating Min[d]
(A) Non-acidulated $NaHCO_3$ Solutions	0	0	2	100	0	0	74	0
	12	0	0	100	Trace	0	69	8
	22	10	0	50	23	0	53	14
	47	25	0	23	37	Trace	43	30
	62	50	0	0	42	3	21	40
	112	100	0	0	27	11	20	70
(A) plus 49 ppm H_2SO_4	0	0	48	36	0	0	74	0
	12	0	10	36	0	0	36	8
	22	10	0	19	8	0	20	14
	47	25	0	2	16	Trace	14	30
	62	50	0	0	12	3	9	40
	112	100	0	0	7	6	5	70
(A) plus 73 ppm H_2SO_4	0	0	70	6	0	0	74	0
	12	0	14	6	0	0	18	8
	22	10	0	0	3	Trace	3	14
	47	25	0	0	1	1	—	30
	62	50	0	0	Trace	2	—	40

[a]Table constructed from laboratory work by E. P. Partridge.
[b]Calculated assuming 143 deg rise in water temperature was effected with 1151 Btu steam. All values in 2nd and 3rd columns are quantities of steam as per cent of the weight of water heated.
[c]This is in addition to the amount required to bring water up to the boiling point.
[d]Computed upon basis of rate which distillate was formed, i. e. about 8 cc per min.

Air Conditioning Combats Common Cold

Air conditioning has proved effective in combatting the common cold because "infective agents do not thrive in the respiratory tracts of people under ideal air conditions," Dr. A. G. Young declared before an engineering meeting of the Boston Air Conditioning Bureau held recently. Dr. Young, medical director of the completely air conditioned Corey Hill hospital in Brookline, Mass., has been in charge of experiments on the effects of air conditioning on health.

The common cold—which he described as an infection in the nose and upper pharynx—can be spread either by direct contact or through droplet infection as a consequence of sneezing, coughing, or even conversation.

"Although we do not know the exact cause of the common cold, we believe that the causative organism is present in the nose and throat most of the time in a low grade form. Excessive fatigue, exposure to dampness or cold, overheating, drafts, and sometimes the consequence of severe nervous exhaustion will lower resistance of an individual sufficiently to permit organisms to gain entrance to the body and thereby invoke the disease," he said.

In cold weather the humidity of the room becomes excessively low, producing an irritation to the mucous membrane of the nose and throat, which leaves people vulnerable to infection, he explained. Also, when an infected individual sneezes or coughs, the droplets spread over a much greater area than if the room were properly humidified.

It has been demonstrated that the human body functions best when the temperature of the air is approximately 70 F in winter, and when the relative humidity is about 40 per cent, with a slow movement of the air. By installing air conditioning, it is possible to maintain these ideal conditions and at the same time wash or filter the air—reducing the bacterial content of the air and the debris which irritates the mucous membrane of the nose and throat.

In conclusion, the speaker cited experience in offices where absentee records have been kept before and after the installation of air conditioning. A large utility company, for example, discovered that employee absences due to illness were reduced 29 per cent with air conditioning, while a leading newspaper plant found that absences fell 30 per cent with the adoption of air conditioning.

Diagram Board at Lansing Station Shows the Piping and Valve Layout

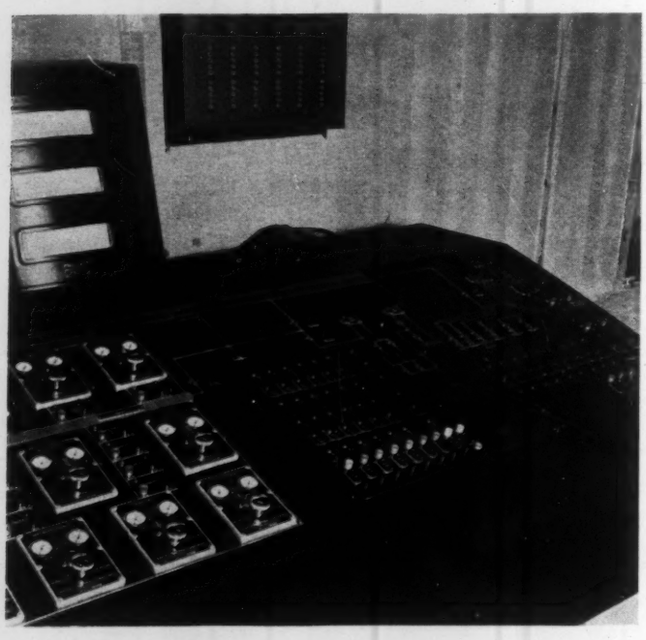
By R. C. Roe*

THE combustion control for the Ottawa St. Station, the new combination electric generating and district heating plant in Lansing, Mich., is entirely automatic and is based on the principle of measuring the air and the fuel before they are supplied to the combustion chamber. In the pre-measuring system the coal supply is regulated to the steam flow and the total air supply is regulated to the coal supply. The term "pre-measuring" is descriptive of the system because both the fuel and air quantities supplied to each pulverized coal burner are weighed en route to the combustion chamber.

In the Lansing installation the pre-measuring principle has been carried further, it is believed, than in any other station. Not only are instruments provided to show the measurement of coal and air to the individual burner groups by weight but in addition, provision is made so that the fuel and air will be automatically controlled on the weight basis to the individual burner groups. This control is actuated by steam pressure and is therefore designed essentially to maintain constant steam pressure automatically regardless of the load of the boiler and at the same time to maintain the correct air-coal weight ratios of the individual groups. Inasmuch as the pulverizers require definite quantities of air for transport and separation purposes with different loads, arrangements have been made to vary the proportion of primary and secondary air with load changes on the pulverizers and at the same time to keep the total of the primary or secondary air in properly predetermined relation with the fuel.

*Burns and Roe, Inc., Engineering Consultants.

This diagrammatic control board at the Ottawa St. Station, Lansing, Mich., indicates the layout of the piping, valve locations, and the relationship of the principal items of equipment. Lights show whether the various valves are opened or closed



Diagrammatic Control Board

As a part of the control there is a mimic diagram of boilers, turbines, evaporators, essential pumps, piping and valves, together with starting and stopping controls for important auxiliaries. Lights are provided to indicate whether the valves are opened or closed and therefore the operator can see at a glance the path of the steam and water circuits between the various parts of a complete boiler turbine unit and can determine accurately that the path is clear for full flows before starting the apparatus. The picture shows the mimic bus construction as well as one of the coal-air indicating meters.

Provision is also made to operate automatically or manually in whole or in part.

The architectural treatment of the exterior of the Ottawa St. Station is also of interest. Surmounting a base of black granite about 6 ft high above the foundation, the brick is in gradually varying shades from purplish dark gray, deep red, bright red, orange, yellow, and finally yellow gray at the top. This treatment is an attempt to symbolize in color the combustion of coal. The stacks extend but 20 ft above the induced draft fans and 12 ft above the roof, and are concealed behind high parapets.

[*Concluded from p. 98*]

as close to normal as possible; i. e. the heating plants were operated by an unskilled superintendent and the windows were opened by the teacher as often as necessary. The measurements were made in February-April. The temperature of the water in the boiler was 149 to 176 F, and the temperature of the inlet water for the panels was kept as low as 81 to 93 F by admixing the cold outlet water. Results of the measurements were:

From February 14 to February 27 the total heat consumption for the radiator heating plant amounted to 20,200 million Btu and for the panel heating plant 14,000 million Btu or 30 per cent less. The radiator heating was much more sensitive to the opening of the windows than the panel plant: opening windows caused practically no increase of heat consumption in the panel plant but caused a very pronounced increase of heat consumption in the other. It should be pointed out that the lower heat consumption of the panel plant was ascertained on week days only; on Sundays and holidays when the boiler temperature sank to 122 F and the temperature of inlet water for the panel heating plant was not lowered correspondingly, the heat consumption of the panel heating plant was higher than for the radiator heating plant.

Complete Control of Piping Systems Eliminates Errors at Campana Plant

By R. D. Frick*

AUTOMATIC control has a prominent place in the processing departments of the Campana plant at Batavia, Ill., where "Italian Balm" and "Dreskin" are made. To facilitate this control each item of equipment—such as tanks, valves, piping, fittings, pumps, scales, photo-electric eyes and timing devices—had to be given careful thought and consideration. The flow of materials from raw state to finished product, bottled, packaged and cartoned for shipment, is for the most part controlled by photo-electric eyes. The heart of the production line is the automatic control of the weighing, proportioning, batching and mixing of the various ingredients throughout the processing department; the specifications covering the handling of these ingredients are very exact, requiring in some instances accuracy within 1/50 of 1 per cent.

When considering pipe for the processing layout the physical and chemical characteristics of the ingredient and materials determined the particular alloy—brass, wrought iron, copper, tin lined brass, nickel alloy, and stainless steel. Also of vital importance was the hydraulics of flow in the piping with various viscosities of liquids, and pitch for drainage. Some dry materials are handled in pipes with their flow controlled by vibrators. Valves of various alloys to match the piping requirements had to be provided, and these valves had to be of such design that their opening and closing could be controlled by photo-electric cell relays.

The automatic control in the Campana processing is for one purpose only, and that is to eliminate entirely human error. The operation of all processing equipment, therefore, is such that the operator cannot put too much or too little of an ingredient into any part of a batch; neither can he leave an ingredient out nor can he add one at the wrong time. The entire sequence (even to the length of time of agitation before, during and after the addition of an ingredient) is automatically controlled. To accomplish this, Campana engineers worked very closely with the scale manufacturer in specifying the functional control and designing the proper electrical interlocking which would assure the exact specified amounts of each material being accurately weighed out and injected in the process at the proper time. This means that in addition to accurately weighing the ingredients, the equipment controls the time elements, opening and closing of valves, starting and stopping of agitators and pumps, and other related operations.

Accurate Weighing Depends Upon Piping

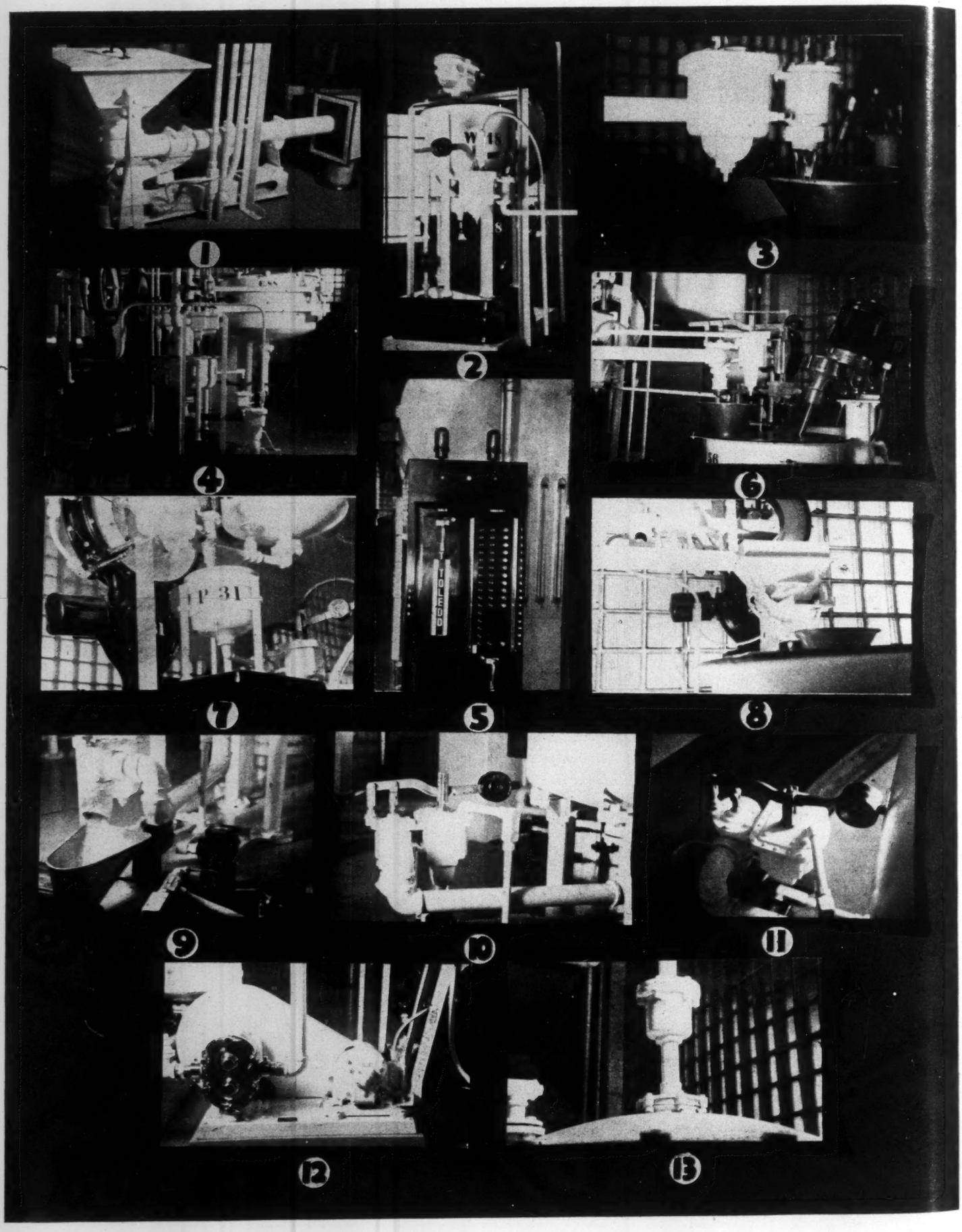
The accurate weighing operation of a photo-electric eye scale is entirely dependent on the design of the piping and valves on the supply and discharge side of the scale tank. Supply valves are situated directly over the scale tanks into which the ingredient is to be weighed. The location of the supply and discharge valves keeps to the minimum the length of pipe leading from the valve to the tank and consequently the retention of any liquid in the piping is negligible. In most instances the valves discharge directly into the scale tanks, as can be seen in the various illustrations. In order to simplify the valve and piping layout and at the same time facilitate accurate weighing (which includes delivery to agitator batch tanks, and precludes retention in pipe lines) Campana engineers made use of the turntable principle. Agitator batch tanks are mounted on a revolving section of the floor so that the tanks will be automatically indexed directly under photo-electric controlled scale positions. The operation of this equipment will be explained later.

The following paragraphs give a brief and not too technical description of the processing operations into which have been incorporated the various principles mentioned above:

The first operation consists of blending high priced essential oils, which is performed on a scale sensitive to 1/100 oz. The exact amount of material is weighed out within a tolerance of 1/50 of 1 per cent. These essential oils are automatically proportioned after they are blended and are mixed with alcohol to make a concentrate of specified quality. The proportioning of this alcohol is performed by a scale with photo-electric eye cut-offs. The concentrate is then pumped to storage above another scale where it is further batched with several other ingredients. All of this processing is automatically controlled by the scale and all electrically interlocked so that diverting valves are opened and agitators are started at the proper time, and each individual ingredient is weighed out with very close tolerance and in proper sequence.

Complete automatic control plays an essential part in the manufacturing operations of the Campana Corp., makers of "Italian Balm" and "Dreskin." Its purpose is to eliminate human error and promote accuracy. . . . Mr. Frick discussed this modern plant at the American Management Association conference reported in the December HEATING, PIPING AND AIR CONDITIONING. Because the piping and valve layout and control is of particular interest, we asked him to write this article specifically for readers of HPAC describing the Campana piping in more detail. . . . Engineers in many industries will, we believe, find pointers in this article they can apply to their own problems; others will be interested to know how completely automatic control can be applied, and the part played by piping in such processing operations as this one

*Plant Manager and Chief Engineer, Campana Corp.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Remote Control Panel Board

The remote control panel board is of particular interest. It has two panels, one for each of two formulas. A production order for a certain number of thousands of gross is routed through the chemical control laboratory, and the chief chemist provides the processing department foreman with a key to open one or the other of the doors on the control panel board. The board is so designed that even though the operator could have two keys (which he does not have) only one door could be opened at a time unless a third key is obtained from the plant manager. This third key is used only when it is necessary to have both panels open at the same time for periodic checking of the controls inside the panel board.

The board is equipped with pushbutton control, automatic interlocking in sequence, time delay switches and indicator lights. For instance, the first button pushed energizes electrically operated solenoid and motor operated valves on pipe lines. As these valves receive energy, a red pilot light opposite the button comes on and after the valves have opened or closed to their predetermined positions the red light goes out and a green light opposite it comes on. Then the operator can proceed with the next step, pushing the second button, which turns out the green light of the preceding step and starts an agitator in a concentrate tank, lighting the red pilot light opposite the second step—and so on down the various steps of the panel board. Each button must be pushed in its proper sequence and even though it is pushed by the operator before the preceding step is completed nothing will happen. After—and only after—all buttons have been pushed in proper order and the program is completed can the door to the panel board be closed. The operator then returns the key to the chemist. The batching equipment is therefore so designed that once the operator starts on a certain batch of material each ingredient is automatically introduced in sequence, agitation takes place at the proper time interval and the batch is completed before the operator can start another batch of the same or a different material.

Fig. 1—Some dry materials are handled in pipes with their flow controlled by vibrators; this view shows a vibrator conveyor and hopper feeding to agitating tank on floor below. . . . Fig. 2—Scale tank on scale platform showing supply and discharge valves; note pressure regulator on supply line. . . . Fig. 3—Solenoid valve discharging from end of scale tank discharge line direct into final batch mixing tank on turntable. . . . Fig. 4—Group of photo-electric eye controlled scales and scale tanks controlled by panel board; tank E-88 is an overhead suspension scale tank and the other tank is supported on the scale platform. . . . Fig. 5—Control panel board with one panel open ready for operation; pushbutton is on right, red operating signal light second from right, and green "complete operation" signal light on left. . . . Fig. 6—Group of solenoid scale tank discharge valves over final batch mixing tanks on turntable; note dashpot to relieve shock of heavy valve closing on end of discharge line. . . . Fig. 7—Small scale tank on scale platform, showing supply tank and solenoid valve above with photo-electric control mechanism to left and solenoid scale tank discharge valve at lower right. . . . Fig. 8—Photo-electric scale control with two vibrator conveyors and hoppers for weighing dry ingredients into pre-mix turntable tank. . . . Fig. 9—Front view showing solenoid valve on final batch mixing tank discharging into funnel in floor. . . . Fig. 10—Side view of solenoid valve on discharge of final batch mixing tank. . . . Fig. 11—Top view of solenoid valve on discharge of final batch mixing tank. . . . Fig. 12—Stainless steel sanitary pump used to pump finished product to final storage tanks. . . . Fig. 13—Flame arrester on vent line from essence tank

Double Orifice Valves Used

The photo-electric beam of light on the scale, when intercepted and when again permitted to enter the photo-electric cell, operates relay circuits. In the case of weighing a liquid from a tank into a scale tank the circuits open and close solenoid supply and discharge valves. The supply valves are double orifice valves having a large supply orifice for speed, which is the first one shut off by the interception of the eye, and a small dribble orifice to drop a pencil stream of the liquid into the scale tank until the exact weight is in the tank. The intercepting shutter of the scale then again releases the beam of light, which immediately closes this dribble orifice. After a few seconds delay the discharge valve from the tank automatically opens and the weighed liquid drains from the tank through the pre-set pipe lines to tanks on the floor below. When the scale tank is empty and the intercepting arm has gone back to its original position the discharge valve automatically closes. Thus, the operator cannot omit or put in too much or too little of any ingredient in the tank, nor can he forget to close the discharge valve so that when he starts weighing up another batch he would run it through the scale tank instead of weighing it in the scale tank.

Possible temporary interruptions of electrical service in no way disrupt these operations. The solenoid valves are normally closed and must have energy to stay open. When electrical service is interrupted and the sequence of batching operations is stopped, all valves close. When the electrical service is re-established the processing batching operations automatically start again at the point at which the interruption occurred and full automatic control is continued.

Tanks Are On Turntables

Following these pre-mix batching operations, batches are delivered to storage tanks from which they are automatically released for the further injection of other ingredients, agitation, milling, filtering and similar processing operations. The Campana engineers have provided a method of handling and further processing these predetermined batches by the use of revolving turntables carrying glass lined tanks with stainless steel propeller mixers. These turntables are automatically indexed at definite intervals, one turntable indexing ⅛ of a revolution at a time, the other ⅙ revolution at a time.

At each indexing position of the table an agitator tank receives injections of new materials pre-weighed and discharged into it by photo-electric eye control scales and cut-offs. These scales are electrically interlocked with each other and with the indexing and timing operations, so each tank receives an exact predetermined amount of material. Any deviation from the established cycle of operations stops everything. In this way the exact amount of ingredients is injected at the right time and with exactly the right amount of uniform agitation, and when the cycle is completed the tank is automatically discharged.

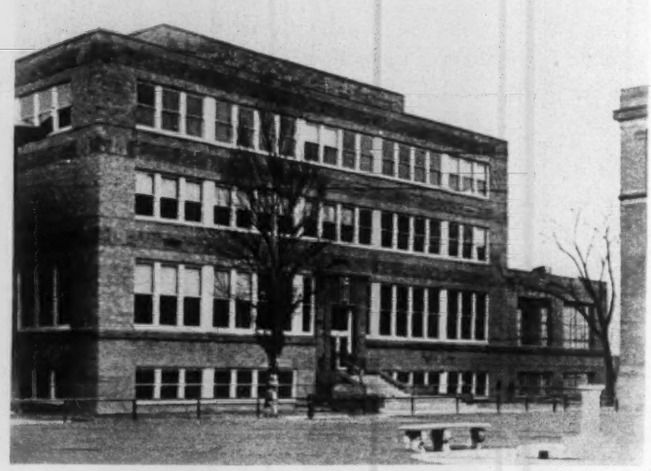
[*Concluded on p. 110*]

Ventilating and Heating a Chemical Lab

By Deane O. Hubbard*

SINCE chemical fumes are frequently disagreeable and often dangerous, their removal calls for a well designed ventilating system. Sometimes the gases do not mix readily with the air and tend to hang in a cloud which is not exhausted from the room unless positive air circulation is provided.

With a system designed to give 15 outside air changes per hour, heating is a major problem as compared to that of an office building with perhaps five changes per hour, part of which may be recirculated air.



The chemical engineering building at Case

Since it is expensive to install corrosion-resistant materials but even more costly to put in non-resistant materials where they may be destroyed by corrosive vapors, it is important that the correct materials for duct work and other equipment be selected.

These were the problems faced by the staff members at the school and by the consultants, Clark, MacMullen, and Riley, in designing the heating and ventilating system for the recently erected chemical engineering building at Case School of Applied Science, Cleveland.

Floor Mounted Units

The problem of avoiding dead air pockets and providing uniform air movement was met by using floor mounted heater-ventilator units. These were placed about 20 ft apart along the outside walls of the room with the air stream directed upward. Thus rapid air movement is produced near the ceiling to aid in removing chemical gases. As the air cools, a downward draft forms, but since the velocity is reduced, the drafts are not noticeable and this movement aids in removing gases from the center of the room. In the laboratories, hoods for special work are provided along one of the inner walls. The amount of air removed at this point depends upon the requirements of the hoods but has little direct value in giving uniform room air movement. To aid in preventing dead air points, there are exhaust ducts with grille openings near the floor and ceiling along the inner walls of the rooms, and above and below the hoods. Each hood and grille opening has a damper.

Since each of the laboratories, which range in size from 20 x 45 ft to 45 x 60 ft and are 13 ft from floor to ceiling, has two outside walls, there was sufficient space for the heater-ventilator units, which were kept to a small size. The plant design laboratory on the first floor, however, is 45 x 80 ft with a 16 ft ceiling and has only one outside wall. To provide the necessary amount of air in this room would have required larger heater-ventilator units than space permitted. For the same reason, it is doubtful if the methods used in the other rooms would be successful. The air, therefore, is delivered by a large single unit mounted outside of the room, and distributed by two large ducts running lengthwise of the room along the ceiling. Narrow horizontal slots in the duct sides produce an air curtain across the ceiling. As in the other rooms, hoods and high and low exhaust grilles provide for exit air.

Preventing Backdraft

To prevent backdraft down ducts that are not in operation, mechanically controlled dampers are installed. Since they open under power when the fan motor starts and are closed by a spring when the power is off, these dampers close in case of power failure.

With the large volumes of outside air used, it must be heated as it enters. To provide flexibility and to avoid extensive duct installations the air is introduced by the heater-ventilator units. Each is equipped with a thermostatically controlled damper set to recirculate the air in the room if the room temperature is too low and to supply heated outside air when the room temperature is normal. Since the rooms do not need an outside air supply all of the time, wall-hung radiators are used for the general heating. The two systems are controlled by the same temperature regulator in each room.

Duct Construction

For ducts that are not subjected to chemical fumes, galvanized sheet iron, painted with an acid resisting enamel, was used. For the outside air ducts in the plant design laboratory and the general exhaust ducts from the laboratories where chemical corrosion is not severe, untreated asbestos lumber was used. These ducts have a rectangular cross section and were assembled with sheet metal angles at the corners and joints between sections. The asbestos lumber was fastened to the metal angles with metal screws and all joints were sealed with an asphaltic cement. Since exhaust air from the hoods may carry more concentrated fumes, impregnated asbestos lumber was used there. Square corner posts inside the asbestos material and flat plates over the joints, each of the impregnated asbestos material, replace the metal angles. Metal screws were used for the assembly and all joints were sealed with asphaltic cement.

*Case School of Applied Science.

The Psychrometric Chart
Its Application and Theory

By William Goodman*

AN ADIABATIC process is defined as one in which there is no loss or gain of heat from an external source while the process is taking place. Thus, when water and air are mixed adiabatically, no heat is added to—or removed from—the insulated chamber in which the mixing of the two is taking place.

Temperature of Adiabatic Saturation

The mixing of water and air adiabatically is not affected by the temperature at which the water is supplied to the chamber. If the process represented by equation 3 is adiabatic, then $Q = 0$, and [3] then reduces to equation 12. As previously stated, [12] is valid regardless of whether the moisture mixed with the air is initially in the form of ice, water or steam. Hence, a mixing process can be adiabatic regardless of the enthalpy or the form of the moisture supplied to the mixing chamber. Furthermore, the air can leave the chamber saturated as a result of being mixed adiabatically with moisture initially in any form and at any temperature.

This is contrary to the general impression that in order for a mixing process between air and moisture to be adiabatic, the moisture must be supplied in the form of liquid and at a temperature equal to the initial wet bulb temperature of the air. This impression is probably due to the fact that Carrier (in his 1911 ASME paper on Rational Psychrometric Formulae) chose the term *temperature of adiabatic saturation* to represent the one particular mixing process in which moisture is supplied in liquid form and at a temperature equal to the initial wet bulb temperature of the air. Any temperature at which air leaves the chamber saturated after an adiabatic mixing process could just as well be called the temperature of adiabatic saturation. Nevertheless, because the term *temperature of adiabatic saturation* is well established, it will be retained here in order to avoid confusion. This term will be applied here only to the one process in which air is adiabatically mixed with water that is at a temperature equal to the initial wet bulb temperature of the air.

Because the term *temperature of adiabatic saturation* is, strictly speaking, applicable to a number of processes, a desirable substitute for it might be *limiting temperature*, suggested for the following reason: In the discussion under "Wet Bulb Temperature" (Part 4, September, 1939, HPAC), it was shown that as the temperature of the water supply is lowered for the process which was illustrated in Fig. 9, the various ratio lines intersect the saturation curve at lower and lower dry bulb temperatures. The temperature of the water for each ratio line and the temperature of the saturated air gradually approach each other until the two are equal. Therefore, the temperature of adiabatic saturation might be called the *limiting temperature*. This term is briefer than the cumbersome *temperature of adiabatic saturation*, and therefore might tend to eliminate the incorrect use of *wet bulb temperature* when the *temperature of adiabatic saturation* is meant.

The Carrier equation for a line of constant temperature of adiabatic saturation is

$$(0.24 + 0.45w_1)\ (t_1 - t_2) = r_2\ (w_2 - w_1) \quad \ldots [25]$$

where t_2, r_2, and w_2 are all taken at the wet bulb temperature of the air.

This equation is applicable only if the air is saturated in the final state. The Carrier equation is a special case of a more general equation for an adiabatic mixing process in which the moisture is supplied at any temperature and in any form—ice, water or steam. As shown in Appendix 6, the following general equation can be derived from equation 4 of the text.

$$(0.24 + 0.45w_1)\ (t_1 - t_2) = (h_{g2} - q)\ (w_2 - w_1) \quad \ldots [26]$$

As is also shown in Appendix 6, if the process is adiabatic, [26] reduces to

$$(0.24 + 0.45w_1)\ (t_1 - t_2) = (h_{g2} - h_o)\ (w_2 - w_1) \quad \ldots [27]$$

Equations 26 and 27 can be used regardless of whether the air is saturated or unsaturated in the final condition. They can be used to compute either the final dry bulb temperature† or the final absolute humidity of air that has been adiabatically mixed with either ice, water or steam *as long as the final condition of the air lies in the clear field of the psychrometric chart or on the saturation curve.* In [27] h_o is the initial enthalpy of the moisture supplied to the chamber; h_{g2} is the enthalpy of the vapor mixed with the air leaving the chamber. The temperature of the vapor mixed with the air is, of course, the same as the dry bulb temperature of the air.

†In order to find the final dry bulb temperature of the air leaving the chamber, the following equation must be used. This equation is obtained by eliminating h_{g2} between equations 10 and 6 of Appendix 6.

$$c_2t_2 - c_1t_1 = (q - 1061)\ (w_2 - w_1) \quad \ldots [26a]$$

If the process is adiabatic, then according to equation 13 of Appendix 6, $q = h_o$. Hence,

$$c_2t_2 - c_1t_1 = (h_o - 1061)\ (w_2 - w_1) \quad \ldots [27a]$$

An interesting feature of the discussion of temperature of adiabatic saturation given this month is the demonstration that the well-known Carrier equation is a special case of a more general equation. Goodman proposes also the use of a new term—the limiting temperature. . . . Psychrometric charts are fundamental tools of engineers engaged in comfort and process air conditioning work, including drying. The series of which this article is a part includes new charts for the low, medium and high temperature ranges, a discussion of the underlying theory, and an explanation of how the various types of problems may be solved

*The Trane Co. Member of Board of Consulting and Contributing Editors.

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Equation 27 is a general equation that applies to any process in which air and moisture in any form are mixed adiabatically. The Carrier equation [25] represents a special case of the general equation [27], and is obtained from [27] in the following manner: If at the end of the mixing process the air is saturated, the dry bulb, wet bulb and dew point temperatures of the air will all be equal. Hence, the quantities w_2 and h_{g2} will correspond to the final temperature t_2. Now, if the moisture mixed with the air is initially in the form of liquid at a temperature equal to the temperature of adiabatic saturation of the air, then it is evident from the earlier discussion under "Wet Bulb Temperature" that the air will be saturated at a final temperature that is equal to the temperature of adiabatic saturation of the air. Hence, at the end of the process the temperature of the saturated vapor mixed with the air is equal to the temperature of the water initially supplied to the apparatus, or

$$h_o = h_{f2} \quad \ldots\ldots [28]$$

Hence, $h_{g2} - h_o = h_{g2} - h_{f2} = r_2$ ..... [29]

where r_2 = latent heat of the vapor at the temperature of adiabatic saturation.

Equation 25 is now obtained by substituting [29] into [27].

In the past, equation 25 has sometimes been applied to any process in which moisture is evaporated into the air and the heat required for the evaporation is supplied by the cooling of the air itself. From the foregoing discussion it is apparent that [25] is applicable only if the liquid is supplied at a temperature equal to the temperature of adiabatic saturation and the air is saturated in the final state. If the liquid is supplied at any other temperature than the temperature of adiabatic saturation, and the air is not saturated in the final state, then [25] is not applicable; the evaporation of the moisture and the drop in temperature of the air take place in accordance with [27], provided that the process is adiabatic. If the process is not adiabatic, then [26] governs.

Symbols Used in Text

(For complete list see p. 358, June, 1939, issue)

- c = humid specific heat of air-vapor mixture ($c = 0.24 + 0.45\,w$)
- d = density of water vapor, lb per cu ft
- d_s = density of saturated water vapor, lb per cu ft
- h_f = enthalpy of moisture in liquid state, Btu per lb of water
- h_g = enthalpy of moisture in vapor state, Btu per lb of vapor
- h_o = enthalpy of moisture in any state, Btu per lb of moisture
- P = total barometric pressure, in. of mercury
- p = partial pressure of water vapor, in. of mercury
- p_s = partial pressure of saturated water vapor, in. of mercury
- Q = quantity of heat added to the air or removed from it, Btu per min
- q = moisture ratio, Btu per lb of moisture evaporated into the air or condensed from it
- r = latent heat of moisture
- t = dry bulb temperature, deg Fahr
- w = absolute humidity of the air-vapor mixture, lb of moisture per lb of dry air in the mixture
- w_s = absolute humidity of saturated air-vapor mixture, lb of moisture per lb of dry air in the mixture
- ϕ_P = percentage humidity
- ϕ_R = relative humidity

Subscript "1" refers to the initial state of the substance and subscript "2" refers to its final state.

Percentage Humidity

Percentage humidity[13] is the ratio of the actual weight of moisture mixed with one pound of dry air to the weight of saturated moisture mixed with one pound of dry air at the same temperature. The weight of moisture per pound of dry air in an unsaturated mixture is

$$w = 0.622\,\frac{p}{P-p} \quad \ldots\ldots [30]$$

and for a saturated mixture

$$w_s = 0.622\,\frac{p_s}{P-p_s} \quad \ldots\ldots [31]$$

Dividing [30] by [31], the percentage humidity is

$$\phi_P = \frac{w}{w_s} = \left[\frac{p}{p_s}\right]\frac{P-p_s}{P-p} \quad \ldots\ldots [32]$$

The term *relative humidity* has been used more widely than the term *percentage humidity*. Relative humidity is defined as the ratio of the actual partial pressure of the water vapor to its saturation pressure at the same temperature. It is expressed by the following relationship:

$$\phi_R = \frac{p}{p_s} \quad \ldots\ldots [33]$$

By an application of the perfect gas laws[14], the following relationship can be derived from [33]:

$$\phi_R = \frac{d}{d_s} \quad \ldots\ldots [34]$$

Equation 34 is valid only at low pressures where water vapor follows approximately the perfect gas laws. In accordance with this equation, relative humidity may also be defined as the ratio of the weight of moisture in one cubic foot of an air-vapor mixture to the weight of moisture in one cubic foot of a saturated mixture at the same temperature. Note that percentage humidity is based on weight of moisture per pound of dry air, whereas relative humidity is based on weight of moisture per cubic foot of humid air. The difference in the numerical values of percentage humidity and relative humidity is small for ordinary atmospheric conditions, and for most purposes may be neglected. Where required, the relationship between relative humidity and percentage humidity can be found by means of the following equation:

$$\phi_P = \phi_R\left[\frac{P-p_s}{P-p}\right] \quad \ldots\ldots [35]$$

This equation is obtained by substituting [33] into [32]. At low vapor pressures the quantity in brackets in equation 35 is very nearly equal to one; consequently, the percentage humidity will very nearly equal the relative humidity. The percentage humidity will always be slightly less than the relative humidity.

In all computations in which the condition of the air is changed, the weight of moisture is expressed in terms

[13] Walker, Lewis and McAdams, Principles of Chemical Engineering 2nd ed., 1927, p. 442.

[14] G. A. Goodenough, Principles of Thermodynamics, 3rd ed. revised, p. 326.

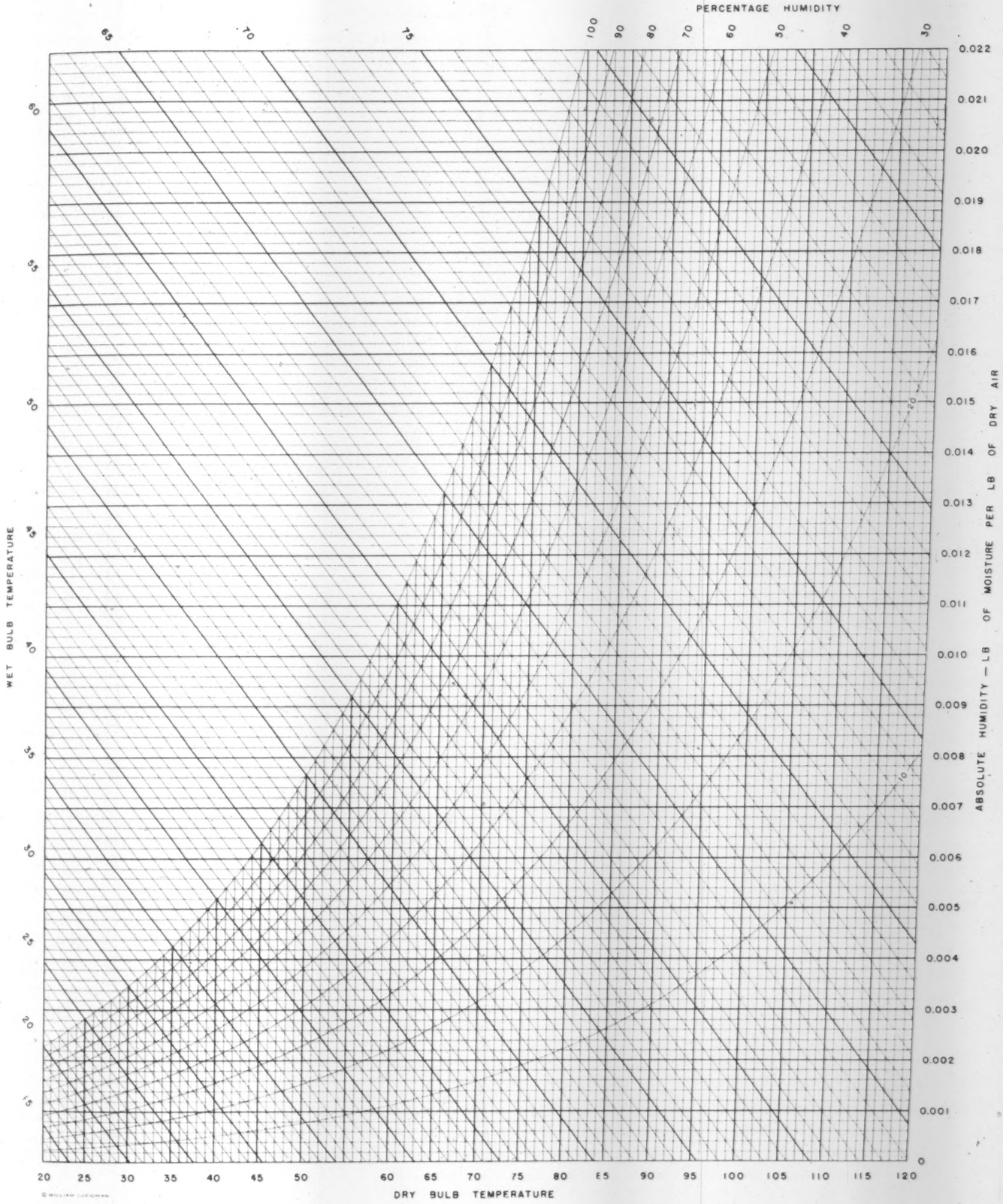


Chart D—This psychrometric chart is to be used only for the normal barometric pressure of 29.92 in. of mercury. Lines of constant wet bulb temperature are shown instead of lines of constant enthalpy. For finding enthalpy at any point, use the psychrometric tables published in either the January, 1938, HPAC or the tables published in January to April, 1939, inclusive. Below 32 deg. slope of lines of wet bulb temperature correspond to enthalpy of subcooled water. For wet bulb lines over ice, refer to Chart F, which will appear in a later issue

of weight per pound of dry air because the weight of dry air in the air-vapor mixture passing through the conditioning equipment is constant. On the other hand, the volume of the air does change as its state is changed. It seems more logical, therefore, to use the term percentage humidity, which is based on weight of air, rather than relative humidity, which is based on volume of air. Relative humidity and percentage humidity can be computed so easily that there is little real need for plotting curves for them on the psychrometric chart.

Example 9: Air at a barometric pressure of 29.92 in. of mercury is at a dry bulb temperature of 75 deg and a dew point temperature of 52 deg. Find: (a) the percentage humidity. (b) the relative humidity.

Solution: (a) Referring to Chart A, (Part 1, June, 1939, issue, p. 359) or Chart D, for saturated air at 75 deg, $w_s = 0.01876$ lb.

For air at a dew point temperature of 52 deg, $w = 0.008229$ lb.

Hence, using equation 32, the percentage humidity is

$$\emptyset_P = 100 \times \frac{0.008229}{0.01876} = 43.9 \text{ per cent}$$

(b) The relative humidity is found by using equation 33.

From the Keenan and Keyes steam tables, for saturated vapor at 75 deg, $p_s = 0.875$ in. of mercury.

For saturated vapor at 52 deg. $p = 0.391$ in. of mercury.

$$\emptyset_R = 100 \times \frac{0.391}{0.875} = 44.7 \text{ per cent}$$

To locate the point representing the state of the air on the psychrometric chart when only the dry bulb temperature and the percentage humidity of the air are known, the absolute humidity of the air is computed first. With both the absolute humidity and the dry bulb temperature of the air known, the point representing the state of the air can be located on the psychrometric chart. The following example illustrates this:

Example 10: Find the absolute humidity of air at a dry bulb temperature of 70 deg and a percentage humidity of 65. The barometric pressure of the air is 26 in.

Solution: Referring to the psychrometric chart (Chart A, Part 1, June, 1939, issue, p. 359) the absolute humidity of saturated air at a temperature of 70 deg and a barometric pressure of 26 in. is

$$w_s = 0.0182 \text{ lb}$$

Therefore, $w = 0.65 \times 0.0182$

$= 0.0118$ lb, absolute humidity of air.

The point representing the state of the air is now located on the psychrometric chart at $t = 70$ deg and $w = 0.0118$ lb.

The terms *relative humidity* and *percentage humidity* have no real meaning for air at temperatures above 212 deg. Saturated vapor at a temperature above 212 deg would, of course, have a pressure greater than the normal atmospheric pressure of 14.7 lb per sq in. For this reason the definition of relative humidity provided by equation 33 has no physical meaning for air at ordinary atmospheric pressure, but at a temperature above 212 deg.

For all temperatures above 212 deg, the percentage humidity of air is zero regardless of the value of its absolute humidity. The reason for this is that the weight of moisture per pound of dry air in a saturated mixture at 212 deg is infinite because there can be no air in the mixture. At all temperatures above 212 deg, it is best to work in terms of absolute humidity when referring to the weight of moisture in an air-vapor mixture.

[*To be continued*]

Campana Plant

[*Concluded from p.* 105]

From the first turntable on the third floor the materials are discharged into a storage tank near the ceiling of the floor below. From here they are automatically fed into tanks on the second floor turntable. Here the materials receive additional injections and agitation in accordance with the pre-set times and quantities, controlled again by photo-electric eye.

From the second table on the second floor the product is discharged from each tank in a sequence into storage tanks below. From these tanks it is pumped through filter presses and special milling equipment, and from there to final storage tanks on the third floor. From these final storage tanks it drains by gravity to the machine lines on the floor below.

Little Maintenance Required

Surprisingly little maintenance is required to keep this piping and processing equipment in efficient operating condition. Systematic check-ups on scales, photo-electric eyes and controls anticipate shutdowns. Most of the piping is stainless steel with sanitary gasket type fittings. The maintenance department has a flaring tool to take care of necessary additions or revisions in pipe lines and has found that accurately timed and intelligent attention licks the problem of maintenance.

The maintenance department is headed by the assistant plant engineer who has two men in his department of maintenance. This assistant plant engineer reports directly to the chief engineer, who happens to also be plant manager.

Air Conditioning and Heating

The air conditioning system in the plant as well as the domestic water service is installed using copper piping with solder type fittings. There are two deep wells with copper bearing steel casings and piping to two pneumatic pressure tanks which are capable of delivering 500 gpm of 52 F potable water.

The boiler plant comprises 12 oil fuel, electric ignition boilers automatically controlled so that they come on and off of the line as temperature conditions in the plant require. These boilers discharge into a common steam manifold which supplies 7 lb steam through an electrical modulating thermostatically controlled steam valve to a heat interchanger. Heating system water is circulated through this interchanger and the air conditioning system. The condensate is trapped from the interchanger to a condensate tank equipped with electric pumps actuated by liquid level switches. The condensate pumps discharge into a common feedwater manifold supplying all 12 boiler-burner units.

During the summer cooling season the hot water and boiler room is valved off the line and the deep wells supply 52 F water through the same indirect surface and convector units.

The Campana plant is open to visitors and a guide is on duty during plant operation hours. All sections of the plant may be observed through plate glass partitions.

How the Courts Look Upon the Air Pollution Nuisance

By Lawrence R. Bloomenthal*

CONTROVERSY frequently takes place in the courts between industrial plants accused of air pollution nuisances and residents of adjoining properties who claim material injury to health and real estate and insist that new equipment be installed or further adjustments made to existing facilities.

The unanimous defense seems to be: Our equipment is of the latest and most efficient design; all local regulations have been strictly observed. What more is necessary? In the majority of decisions, however, the courts have held that in spite of modern equipment and compliance with the law, a nuisance may exist.

Modern Equipment

A large creamery in Kansas argued this point through the lower courts and finally carried the matter to the state supreme court. Here, neighboring residents complained that offensive odors and fumes were being discharged into the atmosphere by ventilating fans and from the exhaust of a diesel engine operating cooling machinery. Upon proof that illness and discomfort had resulted, an injunction was issued forbidding continuation of this nuisance.

Here is a review of various decisions relative to air pollution nuisances created by industrial plants. It is a subject of interest to management, for controversy of this nature frequently takes place. . . . This discussion will give those concerned with the operation of equipment a general idea of the several factors involved

The defendant produced undisputed evidence that both plant and machinery were modern and that the construction and operation of the creamery complied with sanitation ordinances and other municipal regulations. It contended also that since the city had no zoning ordinance and this was not a strictly residential neighborhood, the inhabitants were bound to experience certain inconveniences which were unavoidable. Notwithstanding these facts, the trial court ordered the creamery to discontinue operating in the manner complained of although it gave no specific directions for remedying the situation.

An appeal was carried to the highest court on the grounds that the terms of this injunction were too vague. Because no technical requirements had been set out, there was no assurance that any changes made by the defendant would be considered satisfactory. After reviewing the evidence, the supreme court sustained the injunction, ruling that the contentions of the defendant were immaterial. No business, however lawful or modern, may be carried on in a manner which interferes with the comfortable enjoyment of adjoining residential property. The test is whether persons of ordinary sensibility are adversely affected by odors, noises, gases or other vapors.

Replying to the criticism that the original decree gave no indication of the correct steps to abate the nuisance, the supreme court stated that there is no duty to prescribe the exact methods by which a plant should be re-arranged. This is a technical matter to be determined by consultation with engineering experts.

Ordering Installation of Equipment

Some courts do not hesitate to prescribe exactly what action should be taken to abate an air pollution nuisance. Several years ago, a Pennsylvania manufacturing firm was ordered to install "a reasonable and tried dust collecting device" within 90 days at a minimum cost of $10,000. The power plant of this concern had been operated for many years without complaint until the boilers were changed over from hand firing with ordinary bituminous coal to burning pulverized coal under forced draft.

Following the new installation, inhabitants of a residential community over an area of almost a mile complained of soot damage to their homes, furniture and clothing. Expert testimony during the hearing of an injunction suit disclosed that 3½ tons of waste material per day was being discharged, an unusually high rate for a plant burning 70 tons of coal daily. Conceding the existence of this condition, the defense insisted that it could not be remedied without incurring a prohibitive expense.

In view of the investment of nearly half a million dollars in making the change-over, the courts stated that it considered the outlay of an additional $10,000 for equipment entirely within reason. Consequently, the defendant was instructed to install certain appliances in use in other similar plants so that the amount of refuse thrown on adjoining property would be diminished.

Public Interest Is Involved

There are occasions when the courts uphold atmospheric pollution as being justified. Not only was an Indiana public service corporation permitted to continue its practice of emitting fumes and odors from the chimneys of an artificial gas plant, but the state courts also relieved it of any duty to attempt to remedy the nuisance. In this instance, a greenhouse demanded an injunction as well as substantial damages for injury to its plants, equipment and flowers. Refusing to grant the injunction, the state supreme court declared that public interest in the continued operation of this plant outweighed whatever damage might be caused to private property.

*Attorney and Tax Consultant.

Expert testimony revealed that several million dollars had already been invested and in the present state of the industry it was virtually impossible to operate a gas plant without discharging noxious gases. It was found also that the expense of eliminating the nuisance would impose a financial burden far in excess of the damages already sustained or likely to be inflicted in the future. Since the nuisance was admittedly permanent, $82,750 was awarded to compensate for past, present and future damages to the greenhouse.

Character of Neighborhood

Even when a neighborhood is of a predominantly industrial character, owners of residential property are entitled to freedom from noises and odors which affect their health. Nor does the fact that the complainant voluntarily moved in after the plant was established deprive him of this right. On this theory, a cement corporation was ordered to pay damages for a continuous discharge of dust even though it had originally installed a dust chamber, gradually improved it and finally adopted a standard system of precipitation. According to the evidence, these improvements were not sufficient to obviate the health hazard or eliminate injury to property.

Here again, the defense presented proof that approved methods and appliances were used and that the inconvenience complained of was trifling in comparison with the huge original investment and subsequent improvements. Granting that there was merit in these contentions, the highest court of the state declared that these were not the determining factors. Moreover, it overruled the argument that this condition had existed for so long without serious objection that it had acquired "rights by prescription." Under the laws of New Jersey, there must be open and continuous maintenance of a nuisance for a period of 20 years before it becomes a vested right.

There are some authorities which maintain that the zoning of a section for business or industrial purposes imposes a duty on neighboring home owners to "submit for the public good" to certain inconveniences which might be an actionable nuisance in other sections of the city. According to this line of reasoning, a charge of atmospheric pollution cannot be sustained so long as the industrial concern is complying with all health, fire and police regulations. A reciprocal obligation is imposed upon the industries concerned and all reasonable precautions must be employed to prevent excessive noises or discharges of smoke, gas and other fumes.

Actual Hazards

In those states which uphold the right to complain of nuisances in industrial districts, this privilege is not unlimited. No matter how irritating or disagreeable the situation, there must be a definite hazard either to health or to the value and enjoyment of adjacent property. The Louisiana courts, adopting this viewpoint, reversed a judgment for the plaintiff in a nuisance suit, stating that she was "too sensitive" for a resident of an industrial section.

Surrounding the house in which the plaintiff lived at the time of the alleged nuisance was a railroad, a cotton gin, a rice mill, a sash and door factory and several smaller plants. Yet, when a diesel compressor was mounted on a concrete foundation in a nearby building and the exhaust pipe was attached to a wall 70 ft from her premises, she complained of the noise, fumes and vibrations. After reviewing the circumstances, relief was denied her.

While the discharge of ordinary and unavoidable smoke and odors is permissible in an industrial district, new factories cannot justify the emission of foul gases by pointing out that pollution already exists. In Michigan, an oil refinery was ordered to abate a nuisance resulting from the discharge of sulphur gases. This plant was erected in 1931, using the latest type of stills and other equipment which, witnesses contended, fouled the air only when the wind was from a certain direction. Otherwise, the sulphur fumes were disbursed over such a wide area as to be barely noticeable.

After an injunction had been granted by the lower courts, the refinery appealed, claiming that it was but one of many offenders and that the nuisance, if any, was beyond its power to control. The state supreme court upheld the trial judge and ordered the company to adopt measures suggested by expert witnesses which would effectively control the offensive odor.

Increasing the Nuisance

Because a nuisance is endured when it is slight does not waive the rights of the persons affected to enjoin a more aggravating condition at a later date. In one of the eastern states, a mechanic operated a one-man workshop at the rear of his house where he re-enameled electric refrigerators after removing the original finish with a blow torch. Although the shop was situated in a district restricted to residential occupancy by zoning ordinances, no action was taken by either the city or his neighbors.

The St. Louis *Post-Dispatch* has been conducting a campaign against atmospheric pollution, using pictures such as this one which was taken during the daytime in the downtown area

After several years, the business had expanded to the point where a group of workmen was steadily employed. Although the presence of dangerous fumes was generally recognized and gas masks were worn while spraying paint, no ventilating equipment had been installed. Finally, the owner of an adjoining property 25 ft distant filed an injunction suit to compel discontinuance of the business. The desired injunction was granted on several grounds; the district was exclusively residential, the air was filled with offensive and noxious vapors, and no effort had been made to rectify the situation.

Disturbances at Night

Noises which may be tolerated during the day when there is a steady flow of traffic may become extremely objectionable at night. This is especially true when a large proportion of the property is devoted to residential uses. One of the eastern courts recently used strong language in condemning the inefficient manner in which a bakery was operated. Expert testimony disclosed that while the equipment was but a few years old, ventilating fans had been mounted without employing the proper insulating materials for reducing vibration.

In its opinion, the court stressed the fact that with a comparatively small additional outlay, this difficulty could have been settled long before it resulted in litigation. Nearby owners and their tenants have the right to reasonable rest during the night, particularly when the engineering requirements for alleviating the nuisance are so simple.

Another illustration of a lawsuit which could have been prevented by application of proper operating principles is found in a case involving an injunction suit against a laundry. The complainant charged that between the hours of 7:00 p. m. and 6:30 a. m., it was impossible for members of his family to obtain any rest because of excessive noise and vibration from the washing machinery. In addition, it was necessary to keep all doors and windows securely fastened so as to shut out smoke and soot which poured out continuously during this interval.

The testimony here was strikingly similar to the bakery case in that proper mounting could have prevented transmission of annoying vibrations. Further investigation revealed that the stoker was not being operated according to the manufacturer's instructions, resulting in dense clouds of smoke. An injunction was issued, giving the laundry owner the alternative of ceasing his business entirely at night, or conducting it with due regard to the health, comfort and convenience of his neighbors.

Anticipating a Nuisance

Very often, inhabitants of a residential community will protest the intended erection of an industrial plant, alleging that the entire neighborhood will depreciate in value and that the public health will be affected. As a general rule, courts of equity refuse to anticipate that a new structure will become a nuisance. Accordingly, injunctions are denied unless it can be clearly shown that the proposed business cannot be operated without constituting a nuisance.

Several months ago, the Florida supreme court concurred in this viewpoint. A group of citizens objected to the establishment of a wood pulp mill, claiming that all such plants were bound to pollute the atmosphere with noxious odors and dense smoke. The defense retorted that it had been invited to enter the state by a constitutional provision exempting all mills from taxation and that the manner in which it would be operated was immaterial. While the court agreed that the burdens of a new industry must be accepted along with its benefits, it sent the case back to the lower courts for a hearing on its merits.

The purpose of the hearing was to determine whether the defendant intended to reduce or eliminate the emission of offensive odors so far as possible under presently known methods. Should the mill be able to convince the trial court by means of its building plans and expert testimony that every reasonable means available would be employed to reduce the nuisance factor, they would be permitted to proceed with construction.

Unreasonable Complaints

While industrial concerns are duty bound to heed complaints based upon actual conditions, they are not expected to comply with continual, unreasonable demands. An ice company in Louisiana was faced with this problem. When its motive power was changed over from steam to a high speed internal combustion semi-diesel engine excessive noises, vibrations and offensive exhaust gases resulted. To satisfy protests, the engines were equipped with specially constructed silencers and a wall of double thickness was erected, with a 5 in. dead air space, composed of sound absorption material. Further than this, the company refused to go.

In answer to an injunction suit, it asserted that it had been unusually coöperative and had done everything within reason to alleviate the nuisance. This testimony, coupled with the predominantly industrial character of the neighborhood, caused the court to deny any relief whatsoever to the plaintiff.

The Michigan courts are in accord with Louisiana in limiting the duty to coöperate. The fact that a machine has been invented which it is contended will do the same work without noise, smoke or vibration does not automatically obligate a manufacturer to obtain it. There is no duty to adopt a new device until its practicality has been demonstrated and it is conclusively proved to be in common or general use.

Temperature, Humidity Affect Work Capacity

That temperature and humidity can affect the capacity to do work is shown by miners who rest perhaps seven minutes out of the hour under good conditions, but must lose three times as much time in very hot and damp air, according to the *Industrial Bulletin* of Arthur D. Little, Inc. Even in the moderate climate of England steel workers produce 12 per cent less in summer than in winter. Dexterity of fingers numbed by cold drops sharply at temperatures of 50 F and below, while accidents rise 30 per cent above their optimum levels. These optimum levels seem to be at 63 to 65 F for English workers at light tasks, figures that agree with the statement made 15 years ago by Huntington and Cushing that the best temperature average for humans was 64 F.

Air Conditioning Service Engineer Outlines Method for Leak Testing

By Floyd M. Mayse*

THE air conditioning condensing unit itself seldom needs leak testing, as in most cases the manufacturer has seen to it that his equipment is free of leaks and shipped with a holding charge of refrigerant. However, as it should not be taken for granted that there are no leaks in the equipment when it is installed, the procedure given here will apply to the equipment as well as to the piping. "Freon" will be referred to in this article as it is a common refrigerant used in air conditioning.

Before any connections are made to the system (if a complete system is to be leak tested) we must first determine whether or not it is necessary to leak test the refrigeration unit or condensing unit in conjunction with the piping and coils. As most manufacturers ship their units with a holding charge, the amount of holding charge pressure should be obtained from the manufacturer. It is only necessary to install a pressure gage on the discharge side of the unit, open the discharge valve and read the existing pressure. If this pressure is appreciably below the manufacturer's, then the condensing unit should be leak tested in the same manner as the piping. On systems where a compressor unit only is used, it is difficult in most cases to determine whether or not the holding charge has been lost. Where this cannot be determined by opening an oil pressure gage or other means without losing the holding charge, it is then advisable to leak test the compressor unit also. The reason for not leak testing a condensing unit or compressor unit unless absolutely necessary is because of the moisture that could be admitted.

In this practical discussion, Mr. Mayse outlines in detail the procedure for testing an air conditioning installation for leaks in the piping and equipment. . . . . His recommendations are based upon his own experience in this work

If the condensing unit or compressor unit is to be leak tested along with the piping and coils, the testing lines from the test drums and the vacuum pump can be connected directly to the gage ports on the liquid line and suction line valves. If the holding charge in the units indicates that no leakage has occurred, it will be necessary to install auxiliary valves, in the suction and liquid lines (see sketch) in order to bypass the unit. *Note:* Do not depend on a one line connection to the system at any time. Best practice is to make a direct connection to both the high and low sides of a system. Any control devices that may be injured due to the test pressure used should be valved off or blocked out of the system until the leak tests have been completed.

After all work pertaining to the installation has been completed (that is, all electrical wiring, including the control circuits, etc., all water piping and drains) the vacuum pump, manometer, pressure gage and "Freon" drum should be connected as described above and as shown in the sketch. The "Freon" drum should be set upright since refrigerant vapor only is required for leak testing.

Leak Testing Procedure

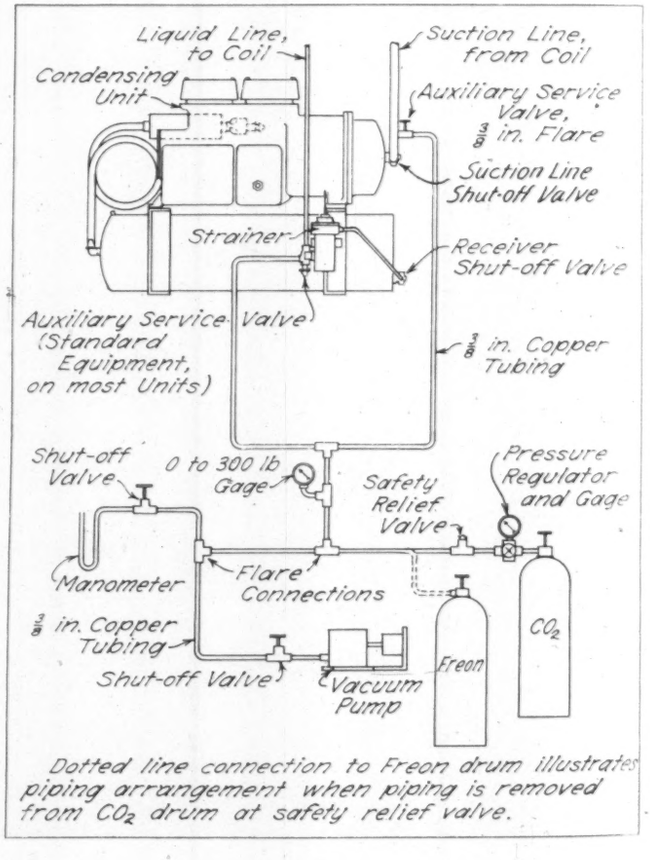
The actual leak testing procedure follows:

1) Make a final check of all piping joints to be sure they have all actually been soldered before applying any pressure. If one or more joints have been overlooked, the piping will blow apart violently if it is suddenly subjected to pressure, with probable injury to anyone in the vicinity or to the refrigerant lines.

2) Open the two auxiliary valves on the liquid and suction line or the liquid and suction line valves on the refrigeration unit, as the case may be.

3) Open the "Freon" drum valve and allow vapor to flow

Diagram showing typical testing connections


Liquid Line, to Coil
Suction Line, from Coil
Condensing Unit
Auxiliary Service Valve, 3/8 in. Flare
Suction Line Shut-off Valve
Strainer
Receiver Shut-off Valve
Auxiliary Service Valve (Standard Equipment, on most Units)
3/8 in. Copper Tubing
Shut-off Valve
0 to 300 lb Gage
Safety Relief Valve
Pressure Regulator and Gage
Manometer
Flare Connections
3/8 in. Copper Tubing
Shut-off Valve
Vacuum Pump
Freon
CO2
Dotted line connection to Freon drum illustrates piping arrangement when piping is removed from CO2 drum at safety relief valve.

*Refrigeration and Air Conditioning Service Engineer, Westinghouse Electric & Mfg. Co.

slowly into the piping system until a pressure of approximately 30 lb per sq in. is reached. To minimize the expense of refrigerant, it is always advisable to test for leaks at 25 or 30 lb as large leaks may be found very easily and repaired before an excessive amount of refrigerant is used.

4) Disconnect the "Freon" drum and connect in its place a drum of anhydrous carbon dioxide.

Note: Use only anhydrous (dry) carbon dioxide and not commercial carbon dioxide which may contain water. Dry air may be substituted for carbon dioxide, but *under no circumstances use oxygen, which explodes violently upon contact with oil* (always present in refrigerant systems).

Note: The pressure in a full tank of carbon dioxide is approximately 1200 lb per sq in. It is therefore essential to use a pressure reducing valve and a safety relief valve safely to control this pressure.

5) Admit carbon dioxide slowly to the piping system until a pressure of 150 lb per sq in. is indicated on the 0 to 300 lb pressure gage. The full test pressure of 150 lb per sq in. should be applied for a satisfactory leak test. A line or connection at the farthest point from the CO_2 and refrigerant supply should be broken slightly and a test made to indicate whether or not sufficient refrigerant has been mixed with the CO_2 to insure that a good leak test can be made.

6) Make a complete test of all joints in the refrigerant piping, using soap bubbles to locate leaks. (Leaks also sometimes occur at other points than joints owing to mechanical injury or flaws in the piping.) For the suds test to be valid, it is essential that a complete visual inspection of every joint be made. A flashlight and a dental mirror will be found helpful in checking joints of limited accessibility. The suds solution should be clean and of the proper consistency to bubble freely. It is best applied by means of a small brush, and should be wiped from the joint after testing is completed.

7) Repeat the leak test over the entire system, using the "Freon" leak detector. The technique of using this torch is so important that it is described below in detail.

8) If time permits, apply a static pressure test by letting the system remain under pressure overnight. In a leak tight system, there will be no noticeable difference between the initial and final gage readings. (Where tubing must be installed during building construction before the installation can be completed, some service engineers find it desirable to seal a pressure charge into the lines until the installation can be finished. A pressure gage must be installed to determine whether or not a leak exists. This provides a static leak test over a longer period of time and provides instant indication of any damage which may be done to the lines.)

9) If leaks are found by any of the above tests, discharge the test pressure, repair the leaks, and repeat the tests until all leaks are eliminated. If a leak occurs in a soldered joint, the joint should be removed, properly cleaned, and entirely resweated, rather than patched up in place.

Use of Refrigerant Leak Detector

"Freon" leaks are detected by a specially designed torch, known as a halide torch. Atmosphere suspected of containing "Freon" gas is drawn through an exploring hose into the burner by injector action. The air sample passes over a copper reactor plate in the burner chamber, which is heated to incandescence by the flame. If there is even a minute trace of "Freon" present, the torch flame will turn from its normal blue or neutral color to a characteristic green color as it comes in contact with the reactor plate. The shade of green will depend upon the relative amount of "Freon" present, being paler for small concentrations and darker for heavier concentrations. Excessive quantities of "Freon" will color

Making a halide torch test on an air conditioning installation. *A*—Exploring tube. *B*—Leak detector. *C*—Pressure reducing valve. *D*—Fuel. *E*—Fuel hose

the flame a vivid purple and may even extinguish it by crowding out the supply of oxygen in the air.

A number of halide torches are available on the market, most of which use either acetylene gas or alcohol as a fuel. The picture above shows an acetylene-burning torch in action (note the pressure reducing valve attached to the tank, which should always be used). There are several precautions which must be observed in using such a leak detector to obtain good results:

1) Be sure the reactor plate is in place.

2) Adjust the flame low enough so that it does not extend beyond the top of the burner chimney. A small flame is much more sensitive than a large flame. (If difficulty is experienced in lighting the torch with the small gas flow necessary, block the end of the exploring hose till the flame ignites, then gradually open it.)

3) If the flame persists in burning a white or yellow color the exploring tube is partially blocked with dirt and should be cleaned out.

4) Try the torch in an atmosphere in which there is known to be a small amount of "Freon" to make sure that it is working properly. Make sure air is being drawn into the exploring tube by holding the end of the tube to the ear from time to time.

5) Hold the exploring hose close to the joint being tested to prevent dilution of the sample by stray air currents.

6) Move the end of the exploring hose slowly and completely around each joint. There is a definite time lag between the instant the air enters the exploring hose until it hits the reactor plate. *Leak testing cannot be hurried.* It is a good idea when leak testing to jar the connections slightly with a hammer (do not injure the piping or fitting), which in most cases will show up a poor joint.

7) If a green tinge to the flame is noted at any time, repeat the test in the same vicinity until the source of the "Freon" is determined. Use soap bubbles if necessary to find the exact point at which a leak is occurring after one has been indicated by the halide torch.

8) Do not use the torch in an atmosphere known to be heavy with "Freon," as this will tend to foul it.

9) Always follow a definite order in leak testing so that no joints will be missed.

10) As its name implies, the halide torch will give the same green flame indication in the presence of other compounds similar to "Freon" (notably carbon tetrachloride) as it does for "Freon" gas. Ordinary care is thus required that no other substance except "Freon" is present where the torch is to be used.

11) If an alcohol burning torch is used for leak testing, the proper grade of alcohol as specified by the manufacturer should be used exclusively. Alcohol torches which require air pressure produced by a hand pump for proper operation must not be pumped up or filled in an atmosphere containing "Freon."

Final Test

After the above tests have been made there is still another that can be used to an advantage at the time the system is evacuated and dehydrated. The shut-off valves on the vacuum pump and manometer should not be opened until the test pressure in the system has been released to the atmosphere. With the "Freon" drum connected as shown by the dotted lines in the sketch, and the system again tight, the vacuum pump should be operated until the mercury on the closed end side of the manometer drops approximately ½ in. The shut-off valves in the line to the vacuum pump should be closed and the pump stopped. The system should be left to sit idle at this point for approximately 2 hr and if no change is noted in the mercury it can be taken that no leaks exist in the system.

After a system has been leak tested, evacuated, dehydrated and charged with refrigerant, it should be allowed to operate approximately a week before the lines are insulated or covered. Before the insulation or covering is put on, a visual and halide torch test should again be made of all the connections, including the compressor or condensing unit, for any further leaks that may have developed. If a trace of oil is noted on a fitting or connection, even though the halide torch does not indicate a leak, that fitting and connection should be replaced and repaired.

Practical Piping Problems

Piping Leaks

By W. H. Wilson*

Piping leaks that aren't easily visible cause more trouble, are more wasteful and usually continue longer than the ordinary visible leaks. Those responsible for piping system maintenance should direct particular attention to leaks of this kind, for those that are readily visible will be brought to their notice in other ways, promptly and without delay.

Steam traps on heating systems, process piping, and industrial equipment leaking or blowing through are frequently the cause of trouble in plant operation, as well as adding to operating expense.

An apparent leak that caused considerable trouble in one case was in connection with a fuel oil supply pipe line in a large industrial plant. A building 2100 ft distant from the main plant was supplied with fuel oil from a small steam driven reciprocating pump. The pipe line was in a tunnel passing under a number of railway tracks. A meter near the pump registered the amount of oil consumed. Both pump and meter were in a small pit at the end of the tunnel.

A relief valve with a threaded discharge opening was installed in the pipe line on the outlet side of the meter, possibly because it was more convenient to locate it at that place. The outlet or discharge opening of the relief valve was piped back and connected to the suction line of the pump. This suction line came from the main fuel line of the large plant.

After a long period of successful operation the oil consumption indicated by the meter increased suddenly to such an extent that much time and hard work were spent in going over the pipe lines in the tunnel looking for leaks. Tunnel drains were traced to the sewers, with no results except for weak explanations to the accounting department for the apparent large oil consumption.

Finally it was discovered that the relief valve was discharging into the pump suction. Someone had improperly adjusted the valve on account of a defective gage. It was a simple matter to relocate the relief valve and normal meter readings were restored. While no oil was actually wasted or lost, the time and trouble spent represented a considerable expense item.

*Member of Board of Consulting and Contributing Editors.

Rental Rates for Air Conditioned Office Buildings

In an article by Al Chase in the *Chicago Sunday Tribune* last month, some figures were given on the effect of air conditioning on rental rates in office buildings. Subject of the article was the proposals being considered by tenants of the Insurance Exchange, a large Chicago office building.

One proposal involved construction of a 19 story building in the downtown district which would have 435,000 sq ft of floor area. Ducts would be built in so that air conditioning could be installed later. Another was for the erection of a building with 500,000 sq ft or more, the rental to vary from $1.80 to $2.20, with air conditioning to be 14c per sq ft additional per year.

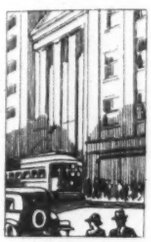
A third proposal involved a new building to have 520,000 sq ft, the rental to be $2.35, including air conditioning. A fourth proposed a building with 700,000 sq ft or more, with a rental of $1.85 and 15c per sq ft additional for air conditioning.

Year 'Round Conditioning System for a Store Has "Three-In-One" Coil

By **Joseph M. Aikman***

THE air conditioning system which was designed by the writer for a ladies' ready-to-wear store in Minneapolis incorporates unique features, including compact arrangement of the equipment, three zones combined in one coil, and the method of control. Among the requirements was the possibility of salvage in case the tenant decided to move to other quarters.

While the cost of operating a well water system for this particular job was estimated to be about 60 per cent of a mechanical system, the initial cost was determined to be about 20 per cent greater, the cost of a small capacity well being greater than a compressor of equal tonnage. There was also the possibility of the water level dropping below the pump unless it was set quite a distance below the present static level, at increased cost. The factor that governed the decision in favor of a mechanical system was that the tenant could remove a compressor, while he couldn't remove a well.



The spaces conditioned are the sales rooms on the first and second floors as shown on the drawings. The building faces nearly west and has large areas of glass on the second floor exposed to the sun. The buildings on the opposite side of the street are not of sufficient height to afford protection from the afternoon sun. The first floor has an arcade, and there is an awning extending over the sidewalk, thereby eliminating sun effect.

Due to the fact that the first floor has no sun effect and has a large number of people, the ratio of sensible heat to total heat is rather low and the second floor ratio somewhat higher, the first floor ratio being 71 per cent and the second floor ratio 84 per cent for both spaces. This necessitated an entering air condition for the first floor entirely different from that for the second floor.

As the number of people in the various spaces fluctuates widely, separate control is provided for each space. It was decided to design a separate coil for each zone and have them built in a single casing with partitions between the sections. The tempering coil has partitions to match those in the cooling coil.

These coils were built in a single casing with galvanized sheets between the sections, making the total face dimensions 42 in. high by 60 in. long. The tempering coil was designed to heat from 40 to 95 F.

The tempering coil is bolted to the "Freon" coil and is located beyond it. The sprays are located between the fan and the "Freon" coils. This was done to save space. The proper order should be, tempering coil, sprays and "Freon" coils, the "Freon" coils acting as eliminators. The "Freon" coils were placed next to the sprays to prevent the spray striking the hot tempering coil. Cold water is used for sprays, the heat necessary to evaporate the water being taken from the air.

There are twelve self cleaning mist nozzles each having a capacity of 1¾ gph, or a total of 21 gph. This is slightly more than twice the requirements to maintain the desired humidity. Allowance was made for the fact that the water is sprayed into comparatively cool air. Tests of this nozzle located beyond a tempering coil have shown an evaporation as high as 80 per cent.

The air conditioning unit is 13 ft long, 6 ft wide, and 4 ft high and is suspended from the second floor ceiling by means of ten ½ in. bolts extending through the floor above. The bolts have countersunk heads and are recessed into 4x4x¼ in. plates which are recessed into the floor and covered by the carpet. The unit comprises filters, fan, motor, humidifying sprays, cooling and heating coils, expansion valves, solenoid valves, and "Freon" piping.

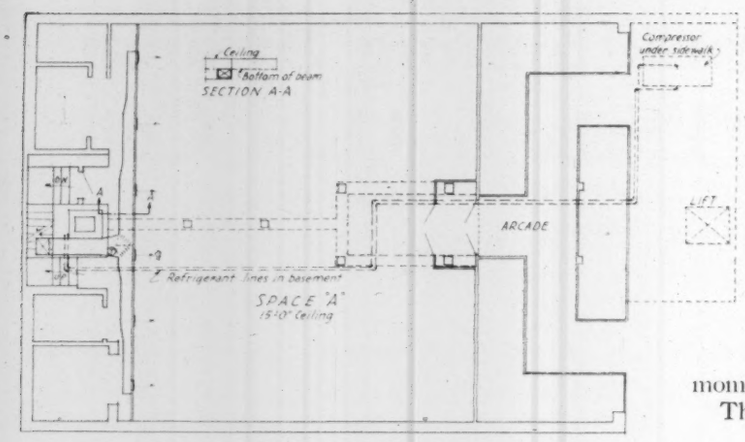
Outside air is taken through louvers in the upper section of the adjacent window. Return air is taken through a large screen in a duct extending to the floor below the unit. The air is distributed through grilles with adjustable blades which were selected with due regard for the length of the blow and the volume of air delivered from each. The return air from the first floor flows up the stair well at the rear of the building. Return air from space "C" flows through the doorway between spaces "B" and "C."

The unit was situated in space "B" instead of "C" to avoid cutting a return air opening in the wall. Space "C" can be cut off by closing the fire door and turning the cutoff damper in the supply duct to this space. The compressor is under the sidewalk and is driven by means of a 25 hp motor. It is cooled by city water which reaches a temperature of 80 F. Liquid and gas lines are run in the basement and rise to the second floor in the stairwell. The compressor is bolted to a concrete block which sets on a 1½ in. cork slab. A concrete curb extends around the concrete block with 1½ in. of cork between the curb and the concrete block.

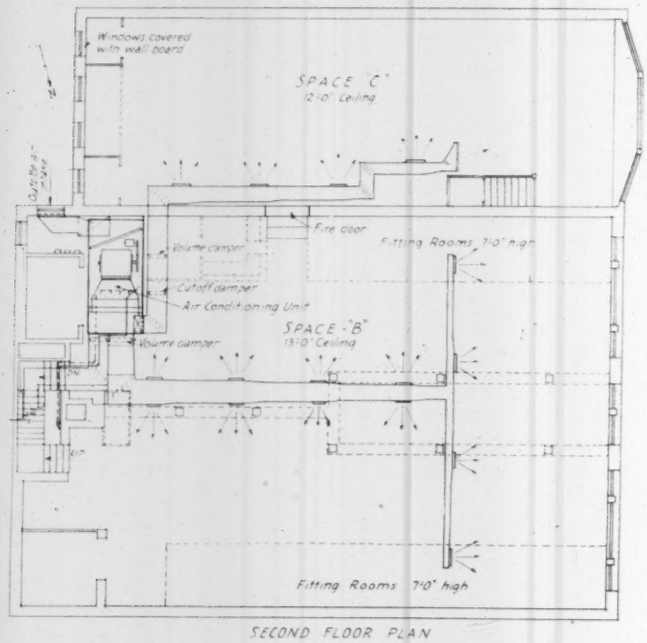
Summer Control System

The temperature of each zone is controlled by means of a modulating compensated thermostat. Each thermostat operates a modulating motor with a switch on each end. The switches are set about 1 degree apart. The first switch to open, closes the solenoid valve feeding the second three rows of tubes in coil "A" for the first floor or the second two rows of coils "B" and "C." The second switch closes the solenoid valve feeding the first three rows of coil "A" or the first two rows of coils "B" and "C."

*Air Conditioning Engineer.



FIRST FLOOR PLAN



SECOND FLOOR PLAN

The compensators are situated in the outside air intake and are set to maintain a 15 F differential at 95 F outside and fade out at 70 F.

The outside and return air dampers are controlled by an economizer in the outside air intake. It is set at 70 F midpoint for winter and 75 F for summer at which temperatures the outside air damper is fully open and the return air damper fully closed. A change of 10 F either side of these temperatures closes the outside air damper, but a minimum opening switch is provided which is set to maintain the dampers in the required position to use approximately 20 per cent outside air as a minimum.

A high humidity limit in the outside air intake cuts down the quantity of outside air as the outside humidity rises above a predetermined setting. A relay is provided so that the outside air damper will close when the unit is not in operation.

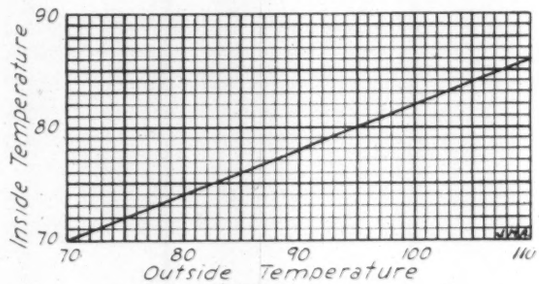
Winter Control System

All of the spaces are heated with direct radiation and the unit merely tempers the outside air supplied for ventilation. A modulating ductstat set at 72 F in the duct for space "B" operates the steam valve on the tempering coil.

Humidity is provided by means of 12 self-cleaning spray nozzles between the fan and the coils. The coils act as eliminators. A solenoid valve turns the water on and off by means of a humidistat situated above the return air grille.

The operator was provided with a table showing the relative humidity that can be maintained at various outside temperatures without causing condensation on the windows, which are single glass. He sets the humidistat according to the outside temperature which he reads from a thermometer placed below the outside air intake.

The system was designed to maintain a dry bulb tem-



Relation between inside and outside temperatures

perature of 80 F with a relative humidity of 50 per cent when the outside dry bulb is 95 F and the wet bulb is 75 F.

Relative Humidity to be Maintained Inside in Winter to Prevent Condensation on Single Glass Windows

Room Temperature 70 F

Outside Temperature	Relative Humidity
65 F	50 Per Cent
60	50
55	50
50	50
45	45
40	40
35	35
30	30
25	25
20	20
15	15
10	10
5	5
0	5
— 5	5
— 10	5
— 15	5
— 20	5

Theater Installs New Air Conditioning

Savings in air conditioning operating costs were obtained when the Kroeschell Engrg. Co. replaced the 15 yr old plant at the State Lake Theater, Chicago. In the new installation the four 40 ton condensing units total but 160 hp, require 200 sq ft of floor space, and weigh 10 tons. The previous two 100 ton refrigerating machines required 250 hp, 1000 sq ft and weighed 83 tons without foundations. The system operates in synchronism with the box office, units being automatically turned on and off according to the number of people.

Heating, Piping & Air Conditioning

AMERICAN SOCIETY of HEATING and VENTILATING ENGINEERS

Journal Section

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The Peripheral Type of Circulatory Failure in Experimental Heat Exhaustion

The Role of Posture

By Robert W. Keeton*, M. D., Ford K. Hick**, M. D., Nathaniel Glickman***, M. S., and M. M. Montgomery†, M. D., Chicago, Ill.

This paper is the result of research sponsored by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS in cooperation with the Department of Medicine of the University of Illinois

IN a previous report[1] the effects of exposure of healthy, human subjects to comfortable, hot dry, and hot wet conditions were noted. When the subjects were placed under the hot conditions there was a maximal dilatation of the peripheral vessels and an increase in circulating blood volume. If there was no rise in rectal temperature, the cardiac output remained unchanged. If the temperature rose above normal there was an increase in oxygen consumption and cardiac output. It is a matter of common knowledge that hot conditions establish in the individual a sensation of discomfort which becomes unbearable as the humidity rises. It is a matter of common experience that under such conditions either heat exhaustion or heat stroke with an associated hyperpyrexia may develop. The latter not uncommonly terminates in death. Evidently such an exposure exacts a strain on the circulation and should prove a useful weapon for the analysis of circulatory adjustments. It seemed wise, therefore, to study critically these adaptations of the circulation in the hot environment. The present report details such studies.

Methods

The subjects were all healthy medical students or nurses. They came in the experimental room in the evening and slept there. About 4:30 A. M. a floor nurse awakened the subjects, who then threw off any covers they had been using and lay quietly on the bed until the observations were begun at about 7:30 A. M. Female subjects wore a costume of short trunks and a brassiere. The males were nude. All subjects were observed 12 hours after the last meal, and after a satisfactory rest. They were therefore under basal conditions. When the conditions of the experiment were such that no one could sleep in the room, the subjects slept in another room on the same floor, were awakened early and moved into the experimental room by 5 A. M. so as to be well adjusted to the environment.

The environments used in this study were approximately as follows: hot dry (99.5 F dry-bulb and 70.0 F wet-bulb), and hot wet (99.5 F dry-bulb and 90.0 F wet-bulb). As control studies the same procedure was followed in comfortable (85.0 F dry-bulb and 57.0 F wet-bulb) and in cool situations (75.5 F dry-bulb and 52.0 F wet-bulb). The air motion was minimal, probably less than 25 fpm at all times. The walls of the room are well insulated and contain no windows. Globe thermometer and thermal integrator readings have consistently shown the wall and air temperature the same, or very nearly so at all conditions

Results

Pulse Rate

A rise in pulse rate on exposure to heat is probably the best known of all circulatory adjustments to hot environments. Haldane[2] observed individuals in a hot room and in Turkish baths and noted that for every 1 F rise in rectal temperature there was an increase of 20 beats of the heart per minute. However, on returning to cool conditions there was an immediate drop in pulse. He concludes that the pulse rate depends not merely on the rectal but also on the external (wet-bulb) temperature.

Under conditions of light work in experiments on himself, Vernon[3] has noted that the relationship between pulse rate and body temperature is rather a complicated question. His experiments covered a rather wide range of temperature. From the individual records of his experiments, he concluded that the pulse rate is more dependent on the air temperature than on the body temperature. However, in a chart which shows the mean results of his experiments, there is a close correlation between body temperature and pulse rate.

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[1]Cardiac Output, Peripheral Blood Flow and Blood Volume Changes in Normal Individuals Subjected to Varying Environmental Temperature, by F. K. Hick, R. W. Keeton, N. Glickman and H. C. Wall. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, January, 1939, p. 50.)

Presented at the 46th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Cleveland, Ohio, January, 1940.

[2]The Influence of High Air Temperatures, by J. S. Haldane. (*Journal of Hygiene*, 5:494, 1905.)

[3]The Index of Comfort at High Atmospheric Temperatures, by H. M. Vernon. (*Medical Research Council Special Reports* No. 73, page 116-1923.)

McConnell and Houghten[4] observed subjects in the sitting position over a relatively wide range of environmental temperatures, and concluded that the correlation between pulse, wet-bulb, and humidity was significant. However, the correlation with effective temperature was slightly better.

Adolph and Fulton[5] also observed subjects in the sitting position, but exposed them "to conditions which cannot be endured by man for an indefinite length of time." In a saturated atmosphere at 105 F they concluded that the heart rate is more nearly correlated with mouth temperature than with skin or rectal temperatures. When the subjects were withdrawn from the room and exposed to cool surroundings, the mouth temperature and pulse rate dropped correspondingly. The rectal temperature, however, lagged behind, remaining elevated for some time. They also noted from a restudy of McConnell and Houghten's data that similar conclusions could be reached.

A graphic correlation of the resting pulse rates with the rectal temperature is shown in Fig. 1 for this study.

This experiment has certain advantages. It was conducted under much simpler and in some respects better controlled conditions than others previously reported. Air currents were not blowing on the subject and he was surrounded by an atmosphere which was at the same temperature as the walls. He had reached a steady state before either the pulse or rectal temperature was taken except in the hot wet conditions. In many of these experiments he had slept in the environment. In others he had been exposed to it for 3 hours. His energy expenditure was at the basal level since no work was performed or food taken.

Throughout all the experiments except those in the upper range, where the rectal temperature rose above normal, there was no increase in oxygen consumption. Correlation between the rectal temperature and the pulse rate is good. Hence, under the conditions of the experiment one would have to conclude that the increase in the temperature of the blood in some way affects the pace maker of the heart and accelerates its rate.

For the purposes of analysis one may divide the experiments cited in the literature into two phases, the experimental phase and the recovery phase. From recent studies[6, 7, 8, 9, 10, 11] it is now appreciated that the body makes many adjustments directed towards the maintenance of body temperature. In the lower range of temperature heat loss by radiation and convection is important, but in the higher ranges evaporation is the determining factor. Hence, it is obvious that if one correlates pulse

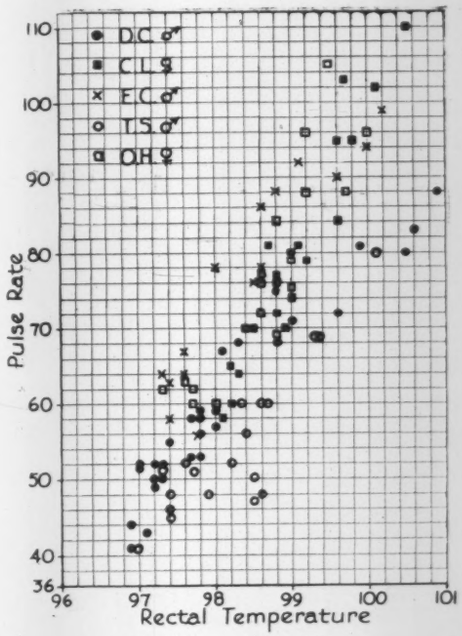

Fig. 1—Pulse rates from five subjects are shown in relation to the rectal temperature. All subjects were lying down and at "basal" conditions

rate, which is an index of cardiac work, with factors in the environment, a factor should be selected operative through the entire temperature ranges. The dry-bulb is the only factor so operative. Investigators are agreed[12] that pulse rate and dry-bulb do not vary together. The best correlation is with the wet-bulb within the ranges where it becomes effective in raising the body temperature. Hence, there is good reason to accept the correlations of McConnell and Houghten[13] in the upper temperature ranges. Adolph and Fulton[14] correlate the pulse rate with mouth temperature changes. The data of Haldane[15] and of Vernon[16] also indicate a correlation with body temperature. One must conclude, therefore, that under conditions of rising temperature, if a steady state can be obtained, the pulse rate will be determined by the body temperature.

Haldane, and Adolph and Fulton, have found difficulty in accepting this conclusion because of the sudden drop of the pulse in the cool recovery atmosphere while the rectal temperature remains elevated. This presents no difficulty. The pulse rate could not be expected to be controlled entirely by one factor. In the recovery with exposure to cool air, evaporation is lessened, radiation becomes active, peripheral vaso-constriction sets in and the blood volume is shifted: Hence, the pulse rate now becomes subjected to the control of different physiological mechanisms.

Arterial Blood Pressure

The arterial blood pressure of these resting subjects, taken while they were lying flat in bed is detailed in Table 1. It should be realized that the readings were taken on different days. Experimental conditions did

[4]Some Physiological Reactions to High Temperatures and Humidities, by W. J. McConnell and F. C. Houghten. (ASHVE TRANSACTIONS, Vol. 29, 1923, p. 129.)
Further Study of Physiological Reactions, by W. J. McConnell, F. C. Houghten and F. M. Phillips. (ASHVE TRANSACTIONS, Vol. 29, 1923, p. 353.)
[5]Effects of Exposure to High Temperatures upon the Circulation in Man, by E. F. Adolph and W. B. Fulton. (*American Journal of Physiology* 67:573, 1924.)
[6]Physiological Reactions of the Human Body to Varying Environmental Temperatures, by C.-E. A. Winslow, L. P. Herrington, and A. P. Gagge. (*American Journal of Physiology*, 120:1-1937.)
[7]The Mechanism of Heat Loss and Temperature Regulation, by E. F. Du Bois. (Lane Medical Lecture, *Stanford University Press*, 1937.)
[8]Life, Heat, and Altitude, by D. B. Dill. (*Harvard University Press*, Cambridge, 1938.)
[9]Role of the Extremities in the Dissipation of Heat, by W. G. Maddock and F. A. Coller. (*American Journal of Physiology*, Vol. 106, 589, 1933.)
[10]The Effect of Changes in Environmental Conditions on Skin Temperatures and the Dissipation of Heat from the Body, by C. Sheard, M. D. Williams and B. T. Horton. (*Proceedings American Physiological Society*, 1937, page 147.)
[11]The Application of the Theory of Heat Flow to the Study of Energy Metabolism, by A. C. Burton. (*Journal of Nutrition* 7:497, 1934.)

[12]Loc. Cit. See Notes 1 and 4.
[13]Loc. Cit. See Note 4.
[14]Loc. Cit. See Note 5.
[15]Loc. Cit. See Note 2.
[16]Loc. Cit. See Note 3.

Table 1—Arterial Blood Pressure[a] (mm Hg)

Subject	Condition	Systolic	Diastolic	No. of Observations
C. L. Female	Cool	120–102	78–68	4
	Hot Dry	122–110	72–62	8
	Hot Wet	130–128	78–60	3
O. H. Female	Cool	114–106	72–68	4
	Hot Dry	118–100	68–58	8
	Hot Wet	120–106	82–64	3
J. W. Male	Cool	120–112	88–76	3
	Comfortable	118–112	92–78	3
	Hot Dry	128–116	84–70	5
	Hot Wet	136–122	80–58	5
W. C. Male	Cool	126– 98	72–60	3
	Comfortable	106–102	72–62	3
	Hot Dry	112–106	78–70	5
	Hot Wet	122–108	76–56	5
D. C. Male	Cool	108–100	72–60	4
	Comfortable	108–100	68–60	4
	Hot Dry	110–102	70–60	5
	Hot Wet	120–104	72–50	9
A. A. Male	Comfortable	110–106	68–68	2
	Hot Dry	112–104	72–58	4
	Hot Wet	110– 92	58–50	2

[a] Subject in lying position.

Table 2—Venous Blood Pressure[a] (mm H_2O)

Conditions	L.	H.	W.	Ch.	Ca.
Cool	113	96	140	101	128
	74	92	152	148	177
	122	99	119	.....	.....
	115	.....	.....	.....	.....
Comfortable	.....	.....	109	125	138
	.....	.....	110	117	116
	.....	.....	109	101	99
	.....	.....	.....	.....	107
	.....	.....	.....	.....	104
	.....	.....	.....	.....	102
Hot Dry	74	73	96	91	82
	72	59	124	96	100
	73	57	102	90	102
	71	39	.....	.....	93
	79	53	.....	.....	91
	70	60	.....	.....	95
	59	.....	.....	.....	84
	77	.....	.....	.....	91
Hot Wet	63	40	126	72	87
	63	93	149	99	111
	90	25	129	106	90
	61	53	148	92	108
	.....	.....	107	105	107
	.....	.....	.....	.....	104
	.....	.....	.....	.....	101
	.....	.....	.....	.....	113
	.....	.....	.....	.....	110
	.....	.....	.....	.....	92

[a] Subject in lying position.

not permit the continuous passage of a subject through all the environmental zones. Hence, there are expected variations in the initial blood pressures. There is not any great change in the observed pressures within the four environments. A lowering of the diastolic pressures in the hot wet environment, where it was previously noted that a maximal dilatation of the peripheral vessels occurs, might be expected. McConnell and Houghten,[17] observing subjects in the sitting position, found some variations in both systolic and diastolic blood pressures. These changes showed the best correlations with the wet-bulb and effective temperature. Adolph and Fulton report one subject (lying position) whose systolic pressure rose 10 mm and whose diastolic dropped to zero after 1 hour exposure to 105.3 F "supersaturated atmosphere." No other data have been found on blood pressures of subjects in controlled hot environments in the lying position. The observations, however, are not sufficiently numerous to be conclusive. The results of this research would speak for the integrity of the mechanism delivering blood to the tissues in the hot environments under these conditions.

Venous Blood Pressure

With a constant blood volume, the venous pressure is responsible for the return of blood to the heart. This pressure is a resultant of three factors: (a) the pressure transmitted from the arterial side through the capillaries, (b) the pressure developed from the tonus of the veins and the surrounding muscular tissues, and (c) the suction due to the negative pressure developed in the chest during inspiration. The positive venous pressure decreases from the periphery towards the heart. As the blood enters the chest the values fall to zero and become negative within the chest cavity. Hence, inevitably the venous pressures vary widely since factors (a) and (b) are not the same in two individuals, and may not be the same in a given individual under all circumstances. However, this pressure must be maintained above a critical level if the blood is to be returned to the heart. In measuring these pressures care must be taken to secure them at the same level with reference to the heart. In these experiments the venous pressure was measured by the direct method of Moritz and Tabora,[18] in which a good sized needle is passed into a large vein at the elbow and blood allowed to rise under its own pressure into an attached manometer tube which is already partly filled with 10 per cent sodium citrate solution. The latter prevents clotting in the needle and manometer tube. The pressure is then measured in millimeters of water and reduced to the level of the auricle of the heart. These data for 5 subjects in the lying position are given in Table 2. All the values fall within the accepted normal levels (40 to 110 mm of water). Therefore, the return of blood to the heart must be adequate in all environments observed with the subjects lying down.

Postural Adjustments

When the human subject assumes the upright position a considerable number of adjustments are necessitated if an undisturbed blood flow to all parts of the body is maintained. These adjustments have been studied in detail, especially by Heymans,[19] but a discussion of them is not indicated at this time. Suffice it to say that an individual may have an entirely adequate circulation in the lying position, but find that it is totally inadequate when he is suddenly placed upright and must make new hydrostatic adjustments. Difficulty in standing after exposure to heat has been described by Leonard Hill,[20] Adolph and Fulton[21] and Bazett.[22] More recently Nielsen, Herrington and Winslow[23] have noted that when their subjects were tilted to an angle of 70 deg they collapsed before routine observations could be completed. The observations previously reported have generally been incidental to other studies. Weiner[24] has reported that 6

[17] Loc. Cit. See Note 4.

[18] Ueber eine Methode beim Menschen den Druck in oberflächlichen Venen exakt zu bestimmen, F. Moritz and D. von Tabora. (*Deutsches Archive f. klinische Medizine*. 98:475, 1910.)

[19] Le Sinus Carotidien, C. Heymans. (Bouckaert and Regniers, Doin, Paris, 1933)

[20] The Influence of Hot Baths on Pulse Frequency, Blood Pressure, Body Temperature, Breathing Volume and Alveolar Tensions in Man, by Leonard Hill and M. Flack. (*Proceedings of the Physiological Society. Journal of Physiology* 38, p. LVII, 1909.)

[21] Loc. Cit. See Note 5.

[22] Studies on the Effects of Baths on Man. I. Relationship between the Effects Produced and the Temperature of the Bath, by H. C. Bazett. (*American Journal of Physiology*, 70:412, 1924.)

[23] The Effect of Posture on Peripheral Circulation, by M. Nielsen, L. P. Herrington, and C.-E. A. Winslow. (*American Journal of Physiology*, 127:573, 1939.)

[24] An Experimental Study of Heat Collapse, by J. S. Weiner. (*Journal of Industrial Hygiene and Toxicology*, 20:389, 1938.)

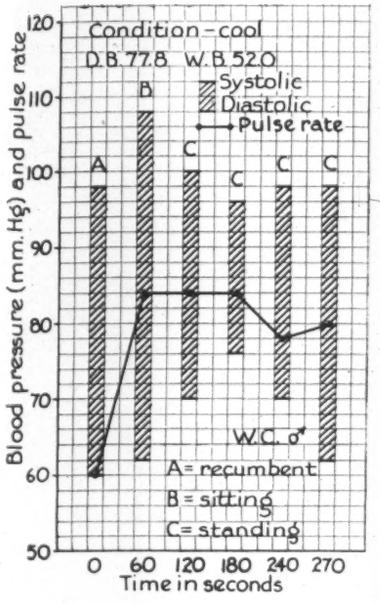

Fig. 2—In a cool environment there was no great change in blood pressure or pulse rate on standing. In a few minutes the blood pressure was identical with the initial level

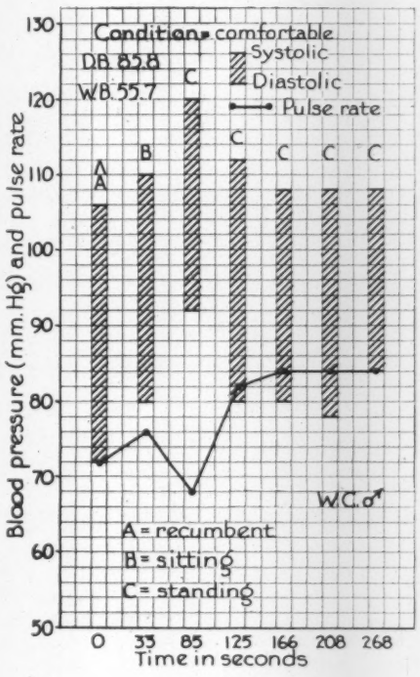

Fig. 3—In the comfortable environment the initial rise in diastolic pressure was significant, but adjustment was rapid. Pulse rate did not exceed 84

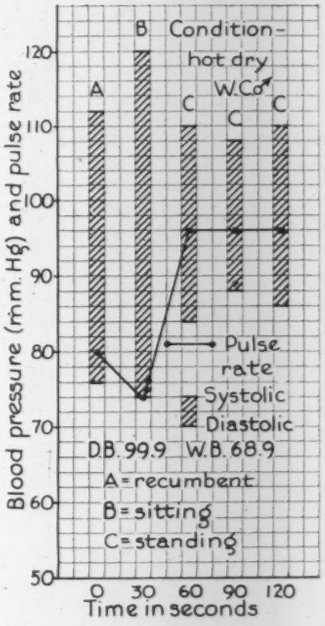

Fig. 4—In hot dry conditions the same subject showed a significant rise in diastolic pressure, a lowered pulse pressure, and a leveling of the pulse rate at 96

out of 36 laborers who were able to work under hot wet conditions were afterwards embarrassed by the erect posture.

Using the same general routine as outlined here, the following observations were added to the list for each morning: The pulse rate and arterial blood pressure were recorded with the subject still lying down. Then the subject sat up on the side of the bed and the pulse rate and blood pressure were again taken. Then on standing these two items were recorded every 30 seconds until either an adjustment was made or until the subject felt faint and chose to lie down.

Six subjects have been studied. The general trend of the blood pressure records is the same in each of this small group. However, they differed somewhat in degree of capacity to tolerate heat. One woman fainted 4 times, one man became dizzy only twice.

The charts present the data from W. C., a medical student aged 22, which was typical. In the cool condition (Fig. 2) an initial slow pulse was associated with a low to normal pressure. On standing up the pulse rose to about 80, the blood pressure changed little and no symptoms appeared. In the comfortable conditions (Fig. 3) the situation was much the same. The blood pressure varied in a moderate degree and the pulse rate rose slightly.

In hot dry conditions this subject (Fig. 4) did not run a fever and was all right while lying down. He had a dry skin, or at times was wet with sweat on limited parts of the body. On standing there was a rise in pulse rate to above 100 and the blood pressure fell moderately, the pulse pressure narrowing somewhat. He was able to stand as long as several minutes with no complaints.

In contrast with the three situations just described, all of which were well tolerated by the subject, come the findings in hot wet conditions (Fig. 5), with the subject having a fever. One graph presents compensatory adjustments; but in the other there is seen a progressive change until the subject chose to lie down. The blood pressure reached a level of 94 systolic and 78 diastolic, a pulse pressure of only 16, and still came back while the pulse rate was above 140. When he became dizzy and chose to lie down, his pulse was about 160 and the blood pressure was 76 mm systolic.

Such ideas about posture are not new. Leonard Hill[25] repeatedly mentioned the difficulty of maintaining an erect posture after a hot bath. Adolph and Fulton presented a theory of heat stroke as a peripheral circulatory failure. Bazett mentioned dizziness, etc., on standing after a hot bath. In a review Bazett[26] wrote the following:

". . . the maintenance of an erect posture, with the consequent tendency for blood to accumulate in the dependent lower limbs, may cause inadequate venous return to the heart, decreased cardiac output and fainting, particularly in a warm environment. Failure of cardiac output, whether produced by a postural change such as that just mentioned or by decrease in blood volume through dehydration, is generated by inadequate venous return."

Apparently those ideas about circulatory adjustment to both heat and posture are matters concerning which physiologists are in general agreement. The data from which such concepts, as described by Bazett, have grown are limited to date.

[25] Loc. Cit. See Note 20.
[26] The Effect of Heat on the Blood Volume and Circulation, by H. C. Bazett. (*Journal American Medical Association*, 11, 1841, 1938.)

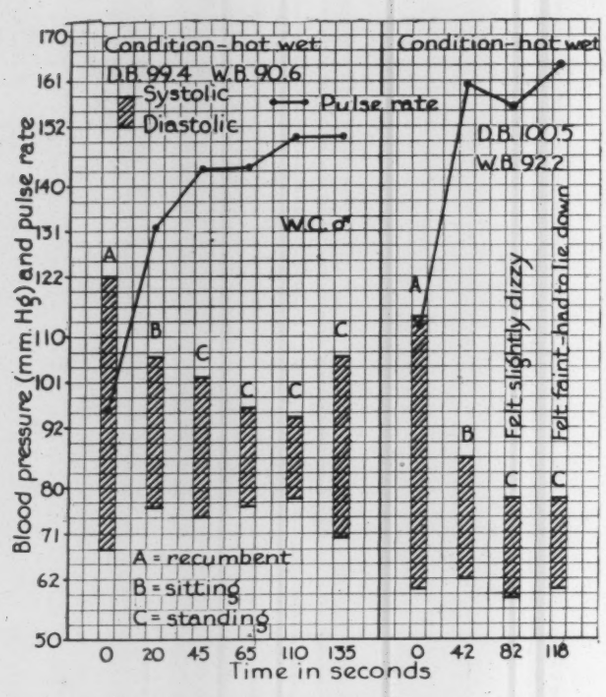

Fig. 5—On the left was the response to the hot wet condition in which the subject adjusted so that he could remain standing. His pulse rate that day reached 150 and his blood pressure fell to 94 over 76, a pulse pressure of 18. On the right, on another slightly hotter day, the pulse went to 164 and, the blood pressure falling quite low, the subject had to lie down

Heat Exhaustion

It is the belief of the authors that the fainting and faintness observed in these experiments constitutes a variety of syncope, a type of failure of the peripheral circulation.[27] There is also some reason to believe that it constitutes *heat exhaustion.*

Whereas the nature of heat cramps has been well worked out and shown to be the result of loss of sodium chloride from the body, there is no unanimity of opinion in regard to the altered physiology in either heat stroke with hyperpyrexia,[28] or heat exhaustion.[29] The careful studies by Dill[30] and others indicate that heat exhaustion is probably not on a chemical basis.

On the basis of the literature already mentioned in this paper, and on observations reported in this study the following theory of heat exhaustion is presented by the authors: On exposure to hot environments sufficient to lead to a retention of heat (i.e. fever), the healthy subject faces increasing difficulty in maintaining a normal circulation while standing or sitting. If sufficiently severe, faintness or fainting follows. A corollary of this theory is that subjects in poor condition, fatigued, or affected by disease, would find these circulatory adjustments more difficult, and would experience symptoms more readily than normals.

[27]The Nature of Circulatory Collapse Induced by Sodium Nitrite, by Soma Weiss, R. Wilkins and F. Haynes. (*Journal of Clinical Investigation* 16, 73, 1937.)

[28]Heat Stroke, Clinical and Chemical Observations on 44 Cases, by E. B. Ferriss, M. A. Blankenhorn, H. W. Robinson and G. E. Cullen. (*Journal of Clinical Investigation*, 17:249, 1938.)

[29]Common Emergencies from Contact with Certain Physical Agents, by E. C. Elkins. (*Medical Clinics North America* 22:1009, 1938.)

[30]The Ill Effects of Heat Upon Workmen, by J. H. Talbott, D. B. Dill, H. T. Edwards, E. H. Stumme, and W. V. Consolazio. (*Journal of Industrial Hygiene and Toxicology*, 19:258, 1937.)

Conclusion

1. Circulation is well maintained in hot environments by healthy subjects while they are lying down, as is shown by normal arterial and venous pressures.

2. The adjustment of the circulation to the erect position becomes increasingly difficult for normals as the environment becomes hotter and fever appears.

3. Failure of this adjustment to the erect posture leads to symptoms of faintness or fainting, and constitutes, in the opinion of the authors, the clinical result known as heat exhaustion.

Correlating Thermal Research

Survey in Seventeen Cement Plants of Atmospheric Dusts and Their Effects upon the Lungs of Seventy-two Hundred Employees, by Leroy U. Gardner and others. *The Journal of Industrial Hygiene and Toxicology*, Vol. 21, No. 7, September 1939, pp. 279-318, 15 tables. This report covers an engineering survey of environmental conditions in 17 cement plants located in various sections of the U. S. Physical and roentgenographic examinations were made of all the employees in eleven of these plants, involving 2278 persons. An attempt was made to correlate the medical findings with the varying kinds and quantities of dust in the atmosphere. "When compared with the dust hazards in hard rock mining and other silica industries, the problem in the cement industry is trivial."

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Ottawa Street, Lansing—Stackless Station of Tomorrow. *Power*, Vol. 83, No. 10, October 1939, pp. 588-591. Also, *Power Plant Engineering*, Vol. XLIII, No. 10, October 1939, pp. 634-646. Description of the central-station power and steam-heating plant built for the city of Lansing, Mich.

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Glass Brick Boiler Plant at H. P. Hood & Sons. *Power Plant Engineering*, Vol. XLIII, No. 10, October 1939, pp. 680-683. Description of the new boiler plant for the H. P. Hood & Sons dairy plant near Boston. The building is of brick and glass brick construction.

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CO_2 Draft and Stack Temperatures, by Frederick I. Lackens. *Coal Heat*, Vol. 36, No. 3, September 1939, pp. 30-33. Discussion in simple terms of principles of combustion. Methods of determining combustion efficiency of a boiler. Use of draft gage and flue gas analyzer.

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Development of Earth Building Blocks, by John Edward Kirkman. *Oklahoma Agricultural and Mechanical College, Division of Engineering Publications.* Publication No. 38, Engineering Experiment Station, Stillwater, Oklahoma, Vol. 9, No. 5, February 1939, 15 pages. Development of waterproof earth blocks for building satisfactory houses which are well insulated, pleasing in appearance, permanent, and very low in cost. Description of Kemo earth blocks. The Kemo blocks are made by mixing earth, asphalt and a chemical solution to a proper consistency in a revolving mixer. This mixture is then tamped or pressed into forms to form blocks. The blocks are taken out of the forms immediately after they are made and stood on boards to set or cure. The solutions used must be varied in proportions and character as required by the quality of earth used. To insure an excellent wearing surface and to obtain adhesion of paint and stucco to the outside surface of the walls, the faces of the blocks are dipped into asphalt treated with inorganic acids and basic salts to set the asphalt so that it will not oxidize. Some details of building construction using Kemo blocks are given.

Advantages of Bactericidal Ultraviolet Radiation in Air Conditioning Systems

By Harvey C. Rentschler* and Rudolph Nagy**, Bloomfield, N. J.

IT is the function of modern air conditioning systems to provide rooms with air that is at the proper temperature and humidity and is practically free from dust and dirt. This is generally accomplished by recirculating the air from the room with the addition of a small amount of fresh air through the necessary heating or refrigeration equipment designed for this purpose. The air in occupied rooms, at times, is highly contaminated with bacteria. Wells[1] demonstrated that bacteria floating in the air may remain in an active state for a considerable time and that air-borne pathogenic bacteria may be responsible for the transmission of certain respiratory diseases.

Ultraviolet radiation of certain wave lengths has long been known to have bactericidal properties and has been

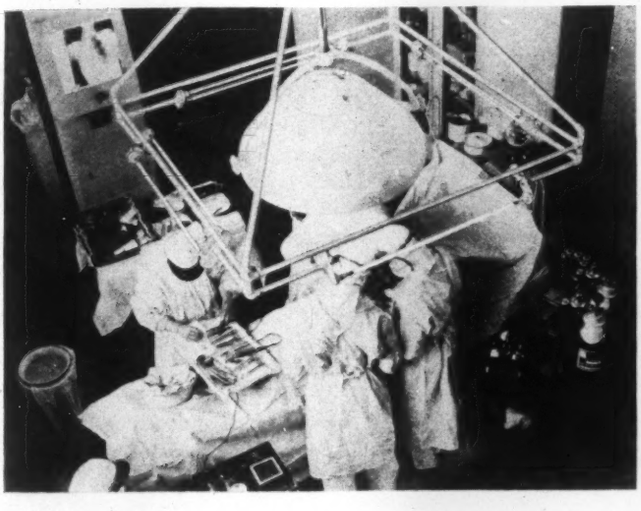

Fig. 1—Ultraviolet lamps over operating table at Duke Hospital, Durham, N. C.

proposed as a suitable agent for killing air-borne organisms. There are three ways such radiation can be applied.

1. *By exposing the air in the room to the direct radiation from an ultra-violet source:* This method is suitable for special cases only, as for example, in hospital operating rooms as shown in Fig. 1 or for laboratory transfer rooms. In such places it is possible for the occupants to protect themselves against excessive exposure from direct radiation.

2. *By the use of semi-direct radiation:* The air in part of the room not directly occupied is irradiated while other parts are shaded from the direct rays. This type of irradiation is particularly suitable for such places as nurseries. A typical arrangement of ultraviolet radiation lamps in a small hospital nursery room is shown in Fig. 2 and Figs. 3 and 4 are photographs of such an installation.

3. *By placing the ultraviolet lamps in the ducts of air conditioning systems:* In this manner all the recirculating air is exposed to the radiation as it approaches and passes the lamps in the duct, an installation of which is shown in Fig. 5.

The work to be described here was undertaken to determine the practicability of adding bactericidal ultraviolet radiation to air conditioning systems. In a recirculating system provided with bactericidal ultraviolet radiation the air would not only have the desired temperature, humidity and cleanliness but would be reasonably free from bacteria as well.

Before an intelligent use of radiation can be made it is highly desirable that the nature of the killing of bacteria by ultraviolet radiation be understood and essential that the factors controlling this action be fully considered.

Hundreds of tests were conducted on various organisms seeded on Petri plates in order to obtain some relative value of their resistivity to ultraviolet radiation. Table 1 will indicate such values. These values were substantiated at various university laboratories especially on those organisms of pathogenic nature. Escherichia coli was selected as an index organism primarily because it is non-pathogenic and because of the constancy of this organism under varying conditions and further because

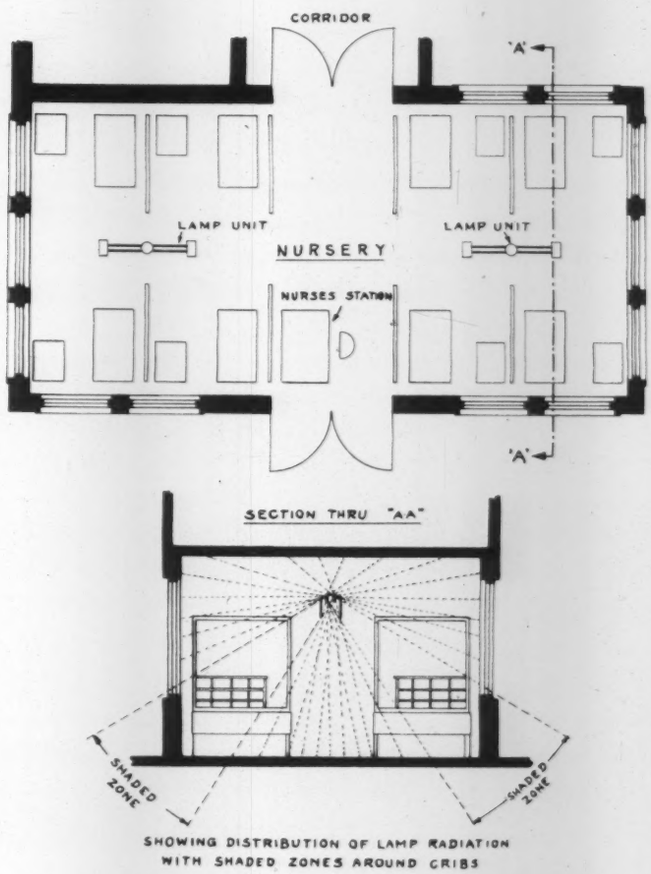

Fig. 2—Shrouded lamp units in infant or new born nursery

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**Biophysicist, Research Laboratory, Westinghouse Elec. & Mfg. Co., Lamp Division.

[1]Air-Borne Infection, by W. F. Wells and M. W. Wells. (*Journal American Medical Association*, 107, 1698 and 1805, 1936).

Presented at the 46th Annual Meeting of the American Society of Heating and Ventilating Engineers, Cleveland, Ohio, January, 1940.

its resistivity is of the same order of magnitude as most of the pathogenic organisms usually associated with respiratory diseases. Values given are arbitrary and were obtained by the use of a special integrating ultraviolet meter.

Method of Measuring Ultraviolet Radiation

The integrated amount of ultraviolet radiation to which the bacteria on a plate were exposed was measured with a tantalum photoelectric cell placed at the same distance from the ultraviolet source as the surface of the seeded plate. Such a cell constructed in the proper ultraviolet transmitting glass has a wave length response very similar to the bactericidal action of the radiation from about 3000A to approximately 2300A. By using an ultraviolet source in the same glass the shorter wave length radiations are absorbed by the glass container and the cell response and the bactericidal action for different wave lengths agree as closely as any tests that can be made.

To measure the integrated amount of exposure, a battery B charges a condenser C proportional to the effective radiation falling on the cell P, Fig. 6. When the condenser is charged to the breakdown potential from a to b of the glow tube G, it discharges from a to b, thereby igniting the glow from d to b, discharging the big condenser K through the electromagnetic counter R, thereby recording the number of times the condenser was charged by the radiation in question.

Factors Controlling Destruction of Bacteria

It is beyond the scope of this article to describe in detail the experiments conducted in establishing the principles of this application. These will be published elsewhere. However the following are briefly a few of the factors which are important in the use of such radiation for the destruction of bacteria in ducts of air conditioning systems.

1. *The bactericidal action is determined by the amount of radiation to which the bacterium is exposed regardless of whether a high intensity is applied for a short time or a low intensity for a correspondingly long time provided that the product of the intensity times the time is the same:* This is known as the reciprocity law as applied to the action of radiation on bacteria.

To prove this, a condenser discharge was passed through a lamp to produce a high intensity of ultraviolet radiation for only a few micro seconds duration. This was found to have the same bactericida effect as when the same total amount of effective radiation wa applied at a low intensity and for as much as several hours a room temperature.

From this it may be concluded that when the exposure o bacteria to radiation in a duct will necessarily be of short dur ation it is both practical and economical to provide sufficien intensity to obtain the total quantity of radiation required fo their destruction.

2. *The lethal action of ultraviolet radiation is not influenced by the temperature of the bacteria at the time of exposure:* A number of Petri plates were seeded with E. coli by a special method so that when not exposed to radiation all of the plates developed approximately the same number of colonies after incubation. A few such plates were incubated without exposure for use as controls. Half of the remainder were then placed in an incubator at 37 C for half an hour and exposed at the same temperature to a definite measured amount of ultraviolet. The rest of the plates were kept in a refrigerator at about 5 C for half an hour and exposed while cold to the same amount of radiation. The percentage of the colonies killed in the two tests was the same within experimental error.

3. *The resistivity of a bacterium to ultraviolet radiation varies appreciably at different stages of its life cycle:* This is indicated in the photograph Fig. 7. A number of Petri plates were seeded alike with E. coli. The upper halves of the plates were exposed to the same amount of radiation but in progressively lower intensities and with correspondingly longer times. This test is an extension of the experiment described herein under reciprocity law only here the bacteria were exposed while passing through one or more life cycles. This increased lethal effect does not signify a breakdown of the reciprocity law but rather a change in the resistivity of the organism at different stages of its life cycle. This test shown in Fig. 7 was conducted at 32 C.

4. *Air-borne bacteria require the same amount of radiation as is necessary to kill the same organisms seeded on the surface of a Petri plate:* This was proved by a long series of experiments so designed that the distribution of bacteria at the different stages of their life cycle was the same at the time of exposure for the air-borne and for those seeded on the surface of the Petri plate.

5. *Air-borne bacteria at high humidity require the same amount of ultraviolet radiation for equal destruction as do the same organisms floating in low humidity air:* This is extremely important for the proper application of radiation for air sterilization in ducts and in high humidity food storage rooms.

6. *In a recirculating system the lethal action of direct radiation is the dominating bactericidal agent:* Ozone which may incidentally be produced by the lamps has an insignificant effect in comparison with the action produced by the radiation itself.

Fig. 3—Semi-direct ultraviolet lamp fixture installed in a New York hospital nursery

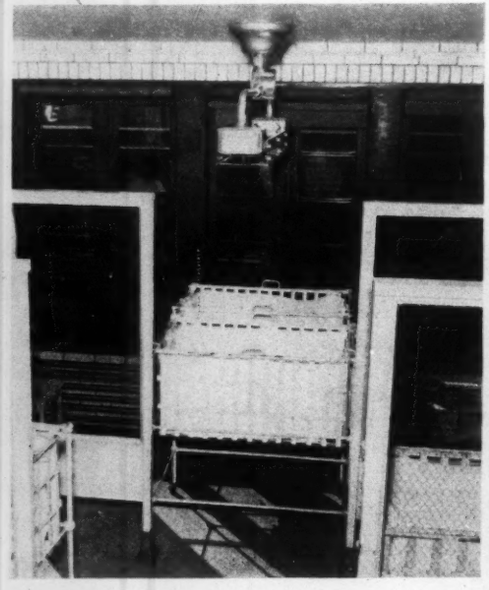

Fig. 4—Same unit as Fig. 3, used as a sterilizing agent for the cribs with infants removed

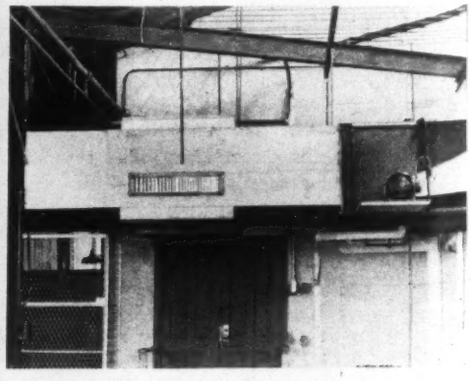

Fig. 5—Radiation chamber in air duct of auditorium air conditioning system

Table 1—Resistivity of Various Organisms to Ultraviolet Radiation

Microorganism	Clicks on Standard Tantalum Cell Meter
Bacteria	95-100 Per Cent Kill
E. coli	25–30
Staph. aureus	24–30
Staph. albus	25–30
Strep. hemolyticus (alpha type)	22–25
Strep. hemolyticus (beta type)	28–35
Shigella flexneri	25–30
E. typhosa	30–35
B. anthracis	50–65
C. diphtheriae	40–50
S. marcescens	25–30
N. catarrhalis	24–35

Lamps and Lamp Characteristics

The radiation from the ultraviolet lamps[2] used in these tests is produced by an electrical discharge between cold electrodes through a mixture of inert gases and mercury vapor in a slender tube of special ultraviolet transmitting glass. These lamps have a high efficiency in producing the desired wave lengths for bactericidal purposes without generating a deleterious amount of ozone. They operate only a few degrees above ambient temperature and, therefore, heat correction in any application is unnecessary. They are commercially available in 10-, 20- and 30-in. lengths. The lamps may be operated singly or as many as four in series on a special transformer. They are reliable in operation, require about 15 watts each, and have a practical operating life of about 4500 hours continuous burning. The lamps produce about 80 per cent of the radiation at or near the most effective bactericidal wave length in the ultraviolet spectrum.

Lamps in Air Conditioning Ducts

The proper installation of the lamps in air conditioning ducts requires considerable care. A definite amount of radiation is necessary to kill a given percentage of the bacteria as they move rapidly in the duct. The intensity of the radiation is greatest at the surface of the lamp and falls off with increasing distance. The most economical use of radiation in a duct, therefore, is under conditions in which there is nearly a uniform intensity through the cross-section. Lamps should be installed in a straight section of the duct in order to utilize the radiation on the bacteria before they reach the lamps and after they pass. While the effect of radiation on organisms diminishes with distance nevertheless the effect is cumulative. In many cases a long straight length is not always available; however, the minimum straight portion of the duct should be at least twice the length occupied by the lamps. In order to arrive at the amount of radiation that must be provided in a given duct the problem is first to determine the intensity at different distances from one lamp and then to find the intensity at any point in an array of uniformly spaced lamps. From these data it is possible to determine an average intensity of radiation along the duct and from this, the length of duct which must be irradiated in order that sufficient energy is supplied to kill bacteria as they pass through the duct. In Fig. 8 the relation between the number of lamps required to produce satisfactory bactericidal action on E. coli and the different volumes of air passing through the duct per minute for a 30 x 30 in. radiation chamber is shown. Fig. 9 gives a similar relation for a 50 x 30 in. chamber and Fig. 10 for a 75 x 30 in. chamber for 5, 10, and 15 in. centers between lamps. As a practical illustration, an air conditioning system with lamps in the duct was installed in an auditorium which was designed to circulate 5800 cfm. Using a 75 x 30 in. duct for the radiation chamber, the minimum number of lamps required for this volume of air and for satisfactory action on E. coli is obtained from the curves of Fig. 10. For 5 in. spacing this number is 57, for 10 in. spacing 33, and for 15 in. spacing 29. Since four lamps can be operated on the same transformer it was decided for experimentation to install 40 lamps in a chamber 75 x 30 in. on 10-in. centers—that is, 5 rows of 8 lamps per row and a lighted length of 40 in. or a total length of 80 in. of treatment duct as illustrated in Fig. 11.

Tests of the Installation

A humidifier was used to spray E. coli into the air of the auditorium. The spray mixture was made by diluting 5 cc of a 24 hour culture of E. coli with 50 cc of sterile broth and 2 liters of water. This mixture was sprayed near the air intake duct using only recirculated air. A Wells centrifuge was used to test the effectiveness of the lamps in the duct by taking samples of air at the outlet grilles entering the auditorium. During these tests the filters were removed so as to obtain the effectiveness from the radiation alone.

Hundreds of tests were conducted to prove the efficacy

[2]Data and observations reported in this paper are based on tests conducted with an ultraviolet source known by the trade mark Sterilamp.

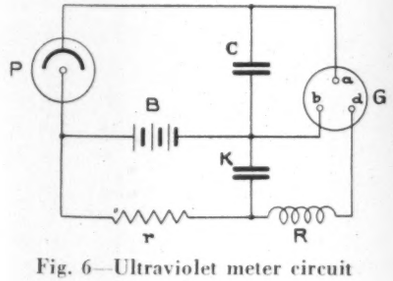

Fig. 6—Ultraviolet meter circuit

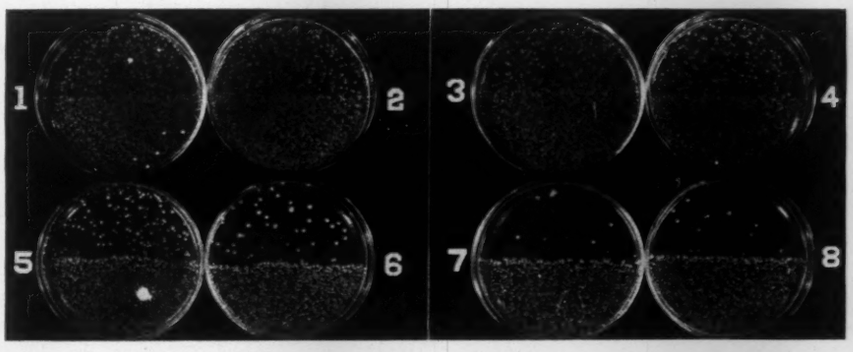

Fig. 7—Seeded Petri plates after exposing upper halves to same total amount of radiation in progressively lower intensities with correspondingly longer times

Exposure times:

1	2	3	4
10 min	40 min	1 hour 33 min	2 hours 43 min
5	**6**	**7**	**8**
4 hours 18 min	6 hours 20 min	8 hours 23 min	10 hours 58 min

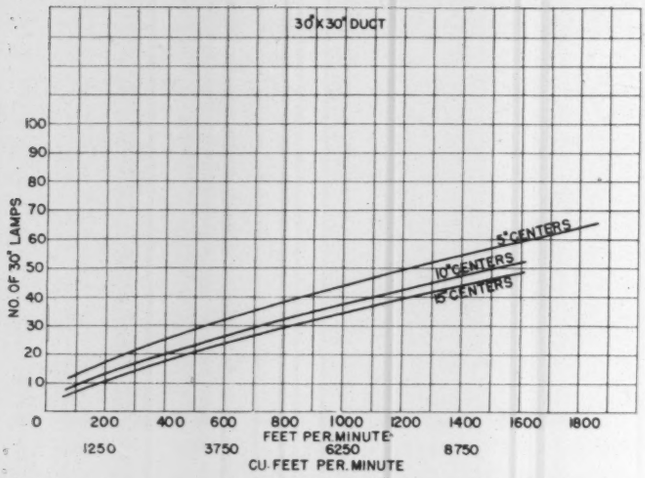

Fig. 8—Curves showing the number of lamps required for varying volumes of air for a 30 in. x 30 in. duct

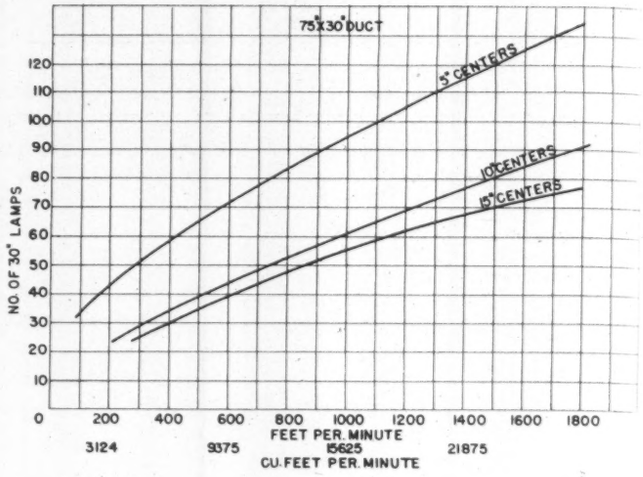

Fig. 10—Curves showing the number of lamps required for varying volumes of air for a 75 in. x 30 in. duct

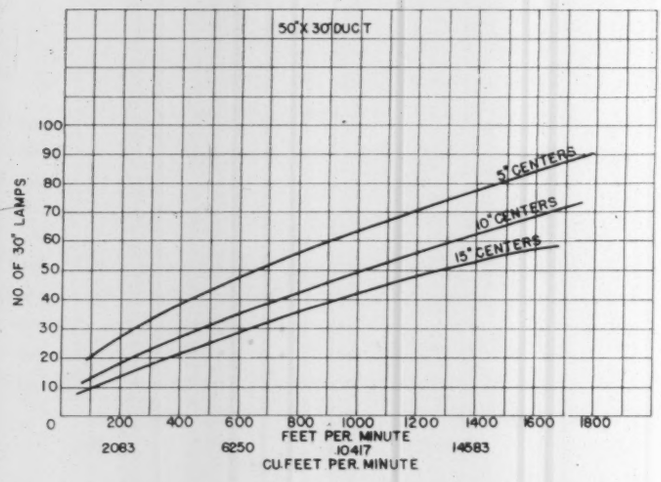

Fig. 9—Curves showing the number of lamps required for varying volumes of air for a 50 in. x 30 in. duct

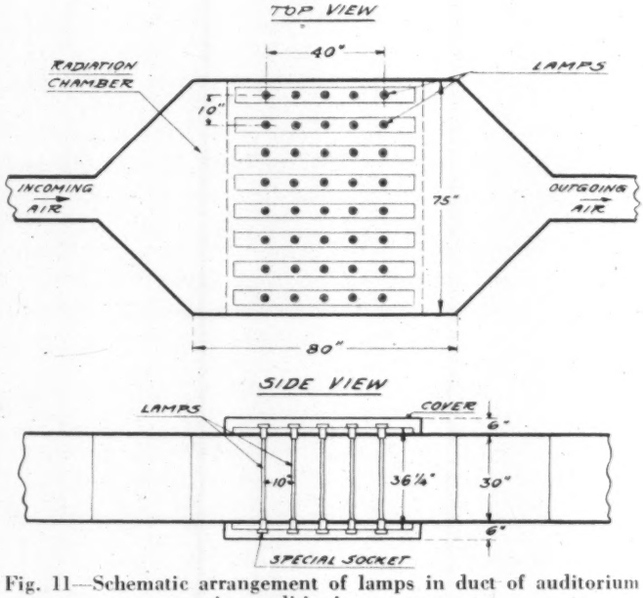

Fig. 11—Schematic arrangement of lamps in duct of auditorium air conditioning system

of this installation under varying temperatures, under varying humidities and with varying amounts of radiation in the duct. The procedure in each test was to take samples of air with the lamps *off*, followed by samples with the lamps *on*, and again with the lamps *off*. From a comparison of the average of the two controls, namely, the first and third, and the sample of the air with the lamps *on* the percentage killed by the radiation was computed. The 40 lamps gave an average reduction of 99.5 per cent while 32 lamps gave a reduction of 98.2 per cent in the number of organisms passing through the duct. Neither the dehumidifier coils of the cooling system nor the filters were found to have any effect in removing bacteria from the air.

Conclusions

1. The use of ultraviolet radiation in air conditioning ducts has been found to be commercially practical.

2. There is no difference in the bactericidal effect of ultraviolet over a range of relative humidity between 35 and 95 per cent.

3. There is no difference in the bactericidal effect of ultraviolet radiation over the normal range of temperature usually found in air conditioning systems.

4. Calculations and curves have been prepared and checked by tests on a practical installation so that the number of lamps required for any given volume of air can be readily estimated.

5. For bacteria with greater resistivity to ultraviolet radiation than E. coli the intensity of radiation must be increased proportionately.

6. The use of ultraviolet radiation for destroying bacteria, when properly applied, has the advantage over other bactericides in that nothing is added or removed from the air.

References

1. An Ultra Violet Light Meter, by H. C. Rentschler (*Transactions, American Institute of Electrical Engineers*, 49, 576: 1930.)

2. The Bactericidal Effect of Very High and Low Intensities of Ultra Violet Radiation, by H. C. Rentschler and R. Nagy (Report presented at *American Association for the Advancement of Science* Meeting at Richmond, Va., December, 1938).

The Performance of Stack Heads

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This paper is the result of research sponsored by the American Society of Heating and Ventilating Engineers in cooperation with the University of Wisconsin.

Introduction

THE purpose of this investigation was to study the effect of approach on the discharge of air from duct openings similar to those used in rooms. Elaborate tables are supplied by various grille manufacturers to show the distribution of air from the grille face, but these tables assume good approach to the grille such as occurs when the grille is placed at the end of a straight duct. In actual installations, however, poor approach conditions are frequently encountered as the grille is often immediately preceded by an elbow turn or stack head. In this investigation chief attention was given to the determination of the velocities and directions of the components of the air stream as they issued from the face of the stack head being tested.

Fig. 1—View of test apparatus

Description of Apparatus

The arrangement used for testing the various approaches, as shown in Fig. 1, consists of a fan for supplying air, a long duct incorporating air measuring devices, a plenum chamber, a stack or vertical duct upon which various approach turns were mounted, and a table with the necessary gages for measuring pressures. Lack of space does not permit complete description of the apparatus except to indicate that the present tests were conducted on a stack head having a dimension of 14 in. x 6 in. Air quantities were measured with a 12-in. x 5-in. calibrated nozzle of the C-2 form reported in Bureau of Standards Research Paper No. 49, installed in a 12-in. duct and checked with the Pitot tube in the 8-in. section of the supply duct.

Air Meters

For determining the air velocities at the stack head faces several instruments were utilized, including the kata-thermometer, the propeller type anemometer, the heated bulb thermometer and the deflecting vane anemometer. A 12-in. wind tunnel with rounded entrance and a 10 ft radius whirling arm were used for calibrations. The deflecting vane anemometer used directly and with a spot reading tip was most satisfactory and was standardized on in these tests. A further check on the accuracy of the instrument and its use was obtained by comparison with the volumes measured at the nozzle. This same instrument with the spot reading tip was also useful along with smoke for determining reverse flow areas.

It was necessary to devise an original instrument to obtain the direction of the air as it leaves the stack head openings. The instrument had to be sensitive enough to indicate the direction of air at the lowest velocities and yet sturdy enough to withstand and record the direction of the highest. The most satisfactory one developed consisted of a carefully balanced balsa wood vane about ¾ in. x 1¼ in., counterbalanced and mounted on a needle shaft with small beads as bearings and supported on a wire yoke and handle. A semi-circle marked in degrees on cardboard was placed at the edge of the stack and a focusing flashlight was used to cast the shadow of the directional indicator on it. This arrangement shown in Fig. 2 made the angle at which the air left the opening at any point readily determinable.

Procedure

In a test of each stack head observations were made of the direction and velocity at the center of each of nine equal areas of the face, the direction at the four edges of the air stream 12 in. out from the face, the distance up from the bottom edge of the face to the point at which zero or reversed flow began; also of the static pressure at the base of the stack head and the pressure readings at the flow nozzle for volumetric determinations. Calculations were made previous to each test to determine the proper gage setting corresponding to 200, 500, 800, 1100 and 1400 fpm stack velocities.

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Presented at the 46th Annual Meeting of the American Society of Heating and Ventilating Engineers, Cleveland, Ohio, January, 1940.

Summary of Results

In Fig. 3 are shown some of the stack heads tested and Fig. 4 is a drawing of these stack heads and the stack used. The lettered dimensions in Fig. 4 refer to dimensions of the 21 stack heads tested as listed in Table 1. In general the heads classify into two types, Nos. 1 to 10 that have rounded backs and 11 to 21 that have square backs. Nos. 1 to 10 classify as round elbow turns and 11 to 21 as square elbow turns.

A summary of test results is given in Table 2 for stack heads 1 to 10 and Table 3 for stack heads 11 to 21. A sketch of the stack head is shown in Column 1, the stack head number, barometer and air temperature are given in Column 2. The relative humidity was not recorded on these tables but was low due to the tests having been made in a space under heated conditions without humidification. The velocity in the 14 in. x 6 in. stack as calculated from the air volume at the flow nozzle is given in Column 3 and the corresponding average face velocity at the stack head opening in Column 4. Stack velocities of 200, 500, 800, 1100 and 1400 fpm are shown. Three sizes of openings were used: 14 in. x 6 in., 14 in. x 9 in., and 14 in. x 12 in. and the average face velocity was found by multiplying the stack velocity by the ratio of opening size to stack size.

Columns 5 to 13 inclusive give the tilt upward of the air stream at the center of the nine equal areas of the stack head openings as shown on Fig. 4. A negative reading indicates a tilt downward from the horizontal. In certain cases the angle was indeterminate due to wide fluctuations and these are marked turbulent. Column 14 gives the divergence of the sides of the air stream measured from a vertical plane midway in areas 1 and 3.

The divergence of the air stream boundary 12 in. out from the opening is given in Columns 15 to 18 inclusive, at the top in Column 15, at the bottom in Column 16, at the right side in Column 17 and at the left side in Column 18. The static pressure at the base of the stack head is shown in Column 19 in inches of water. The location of the four pressure taps is shown in Fig. 4. Static tube traverses at this cross-section indicated agreement with the average from the four static pressure holes. The velocity at the center of each of the nine areas at the plane of the stack head openings are shown in Columns 20 to 28. Negative readings indicate reverse flow into the stack opening. Column 29 gives the arithmetical average of the velocity determined at the center of the nine areas. This may be compared with the average face velocity in Column 4 determined by nozzle measurement. Column 30 indicates the distance up from the bottom edge that negative flow exists. Column 31 shows the static pressure at the base of the stack heads in per cent of the velocity head at the same location.

Fig. 3—Stack heads tested

The results as to directions and velocities of the various parts of the air stream shown in Tables 2 and 3 are shown graphically in Figs. 5 and 6. In these diagrams the velocities found at the face opening were plotted to a convenient scale at an angle equal to the mean angle of the air stream and a smooth curve was drawn through them. Although tests were made at five stack velocities as recorded in Tables 2 and 3, diagrams are shown only for two, namely, 500 and 1100 fpm since they were found to show the behavior adequately. The static pressures at the base of the stack heads are plotted on Figs. 7 to 12 inclusive. In discussing the performance of the stack heads, velocities will be first considered, then directional effects, and lastly static pressure drops.

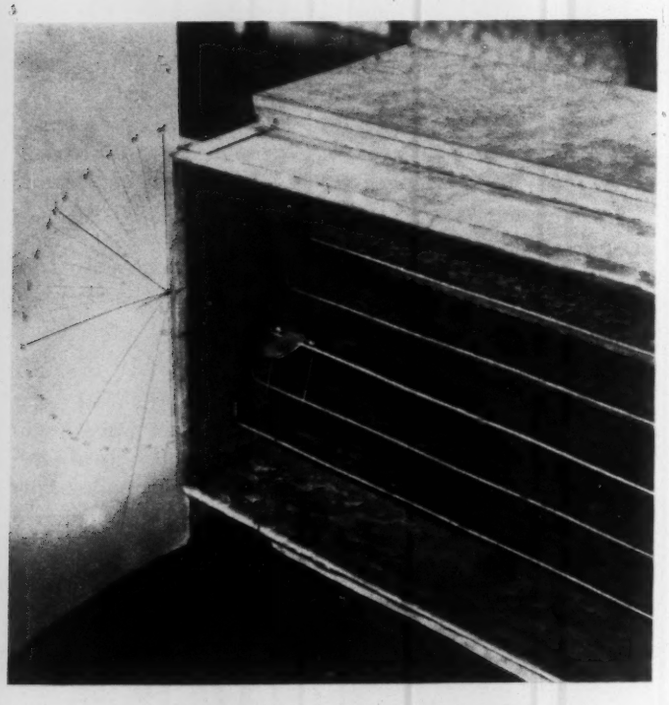

Fig. 2—View of directional indicator

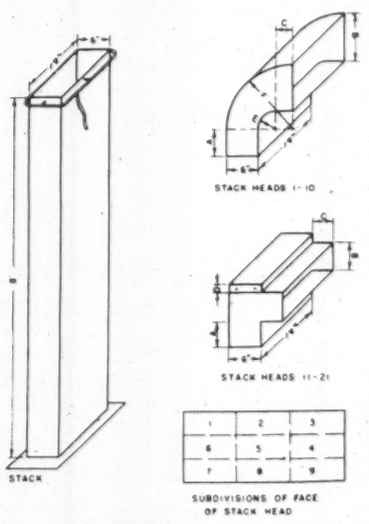

Fig. 4—Diagram of stack and stack heads tested

Table 1—Dimensions of Stack Heads Tested

Stack Head No.	A	B	C	D	E	F	T. V.	Spl'r
1	0	6	0		3	9		0
2	0	9	3		3	12		0
3	0	12	6		3	15		0
4	3	6	3		0	6		0
5	3	9	3		0	9		0
6	3	12	6		0	12		0
7	0	6	0		6	12		0
8	0	6	0		3	9		2
9	0	9	3		3	12		2
10	0	6	0		6	12		2
11	3	6	3	0			0	
12	3	6	3	5/8			0	
13	3	6	3	1½			0	
14	3	6	3	3			0	
15	3	6	3	6			0	
16	3	9	3	0			0	
17	3	9	3	6			0	
18	3	12	3	0			0	
19		6		0	3		0	
20	3	6	3	0			5	
21	3	9	3	0			6	

Stack heads Nos. 1, 2 and 3 were similar having a 3-in. rounded throat radius but having face openings 14 in. x 6 in., 14 in. x 9 in. and 14 in. x 12 in. respectively. A somewhat higher face velocity was found in the middle third of the opening with the 14-in. x 6-in. opening. For the expanding stack heads Nos. 2 and 3 the velocity in the top third was somewhat higher than in the middle third. With the 14-in. x 6-in. opening a small area of reversed flow, less than an inch in height existed which decreased with an increase in air flow. With the expanding stack heads this area of reverse flow became larger, being 5½-in. in height at the lowest air flow and 4¼-in. at the highest air flow with the 14-in. x 12-in. opening. In all three cases the area decreased with an increase in air flow.

Stack heads Nos. 4, 5 and 6 were similar to Nos. 1, 2 and 3 except that the throats were made square instead of with a 3-in. radius. The performance characteristics of Nos. 4, 5 and 6 were found to be quite similar to those for Nos. 1, 2 and 3 of equal face areas. The tendency for the highest velocities to be in the upper third was more pronounced and the reverse flow areas were larger. In No. 6 with the 14-in. x 12-in. opening, the reverse flow area occupied the entire lower half. With an increase in air flow the reverse flow area increased in No. 4 with a 14-in. x 6-in. opening and remained constant with the expanding stack heads. From the results on these six stack heads it appears that the throat radius is the important factor in determining reverse flow.

Stack head No. 7 which had a 6-in. throat radius gave more uniform velocity distribution over the opening than those with a smaller radius. The area of reversed flow was very small at low velocities and disappeared entirely at the higher velocities.

Stack heads Nos. 8, 9 and 10 were equipped with two splitters each and are otherwise similar to Nos. 1, 2 and 7 respectively. In fact No. 1 became No. 8, No. 2 became No. 9, and No. 7 became No. 10 by the addition of the splitters. The reversed flow area was almost entirely eliminated and the distribution over the face opening was made much more uniform. The effect of the splitters was to make the stack head into three stack heads each with a somewhat higher velocity at the top than at the bottom. This gives a scalloped effect as noted in these three diagrams. In No. 9 which expanded to a 14-in. x 9-in. opening the variation from top to bottom of the individual air streams was more pronounced than in the non-expanding heads Nos. 8 and 10. The short radius turn No. 8 showed performance approximately equal to that of the long radius turn No. 10.

Stack heads Nos. 11 to 15 inclusive were tested to determine the influence of varying heights of cushion chambers placed above square type turns. The heights of chambers were 0 in., 5/8 in., 1½ in., 3 in. and 6 in. in order from No. 11 to No. 15. The face opening was 14 in. x 6 in. in all five of these stack heads. The same stack head was used in each case, the change from one to the next in the series being made by substitution of chambers. The purpose of the chamber was considered to be to aid the air in making the turn and thereby make a change from square back characteristics to those of a rounded back. Although the results of these five heads are shown in Table 3, diagrams of only the two extremes, No. 11 with no chamber and No. 15 with a 6-in. chamber are shown in Figs. 5 and 6, since the performance of all was very similar. The velocity was somewhat higher in the top third than in the middle third and this difference increased at the higher velocities and increased a little as the velocity increased. The same comparison was made for the performance of a cushion chamber for stack heads expanding to a 14-in. x 9-in. opening in No. 16 having no chamber and No. 17 with a 6-in. chamber. In each case negative air flow was found in the whole lower third with this area becoming somewhat larger at higher velocities. The velocity distribution was fairly uniform in the upper two thirds with slightly higher velocities in the upper than in the middle third which difference increased with greater air volumes. From a study of the performance of these two series it is concluded that the cushion chamber does not influence distribution.

Stack head No. 18 with a 14-in. x 12-in. opening completes a series of three square turns with No. 11 having a 14-in. x 6 in. opening and No. 16 having a 14-in. x 9-in. opening. The distribution characteristics were quite similar in all three with the highest velocity in the top third, somewhat lower in the middle third and reverse flow in the lower third. The peak velocities were almost in inverse proportion to the opening area. The reverse flow areas increased somewhat, being at 1100 fpm stack velocity, 32 per cent of the face opening in No. 11, 36 per cent in No. 16 and 39 per cent in No. 18.

Two series of stack heads Nos. 11, 16 and 18, and Nos. 4, 5 and 6 compare square throated turns having rounded backs with those having square backs. No great difference was found, the velocity distribution and reverse flow areas being quite similar in the corresponding stack heads. The largest difference was in the reversed flow area being greater with the rounded back turn No. 6 than with the square back turn No. 18. This difference is accountable by No. 6 having a distance from face to stack (dimension *C* Table 1) of 6 in. and No. 18 having this distance as 3 in.

Stack head No. 19 was of the square back type similar to No. 11 except that a throat with a 3-in. radius replaced a square throat. The peak velocities were considerably reduced and the area of reversed flow was decreased from nearly two inches to below 1 in. The influence of the throat radius is quite apparent.

Table 2—Results of Tests on Stack Heads Nos. 1 to 10

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		Stack Vel.	Face Vel.	Angle with Horizontal at Face, Degrees									Angle with Vert.	At 12" Out Degrees				Stack Head	Velocity — FPM										Neg. SP	SP VP
		FPM	FPM	1	2	3	4	5	6	7	8	9	Deg.	Top	Bot.	R.S.	L.S.	S.P.	1	2	3	4	5	6	7	8	9	Ave.	In. W.P.	Per Cent
1	No.1	200	200	20	17	17	22	19	21	30	33	33	6	22	15	5	5	0.0041	240	240	240	240	240	240	130	150	130	205	1/8	172.0
	Bar.	300	300	21	18	22	27	24	25	34	32	34	5	21	16	5	5	0.0169	630	600	630	640	650	640	300	320	300	522	1/8	164.1
	28.95	800	800	20	17	20	26	20	23	25	26	30	4	20	15	4	4	0.0336	960	940	950	960	960	950	370	650	560	833	1/8	94.0
	Temp.	1100	1100	22	15	21	26	22	24	30	26	28	3	24	18	6	6	0.0594	1300	1260	1280	1300	1310	1300	920	970	900	1170	1/8	82.9
	77.1	1400	1400	20	15	20	25	24	26	27	24	28	3	25	18	8	8	0.0904	1740	1660	1660	1720	1660	1660	1200	1250	1200	1520	1/8	84.7
2	No.2	200	133	23	20	22	31	24	27	Turbulent			6	20	16	7	7	0.0024	225	225	225	210	215	210	-25	-30	-25	134	2 1/2	100.3
	Bar.	300	333	22	19	23	28	25	26	"	"	"	5	18	13	7	7	0.0078	330	320	330	490	490	480	-50	-50	-50	321	2 1/2	50.6
	28.93	800	533	23	19	22	20	20	24	"	"	"	5	19	16	6	6	0.0216	910	870	870	840	850	830	-50	-50	-50	538	1 1/2	56.1
	Temp.	1100	733	22	20	22	23	22	24	"	"	"	5	19	16	5	5	0.0399	1230	1200	1200	1090	1150	1070	-50	-50	-50	754	1 1/2	55.3
	72.5	1400	933	22	20	22	25	26	26	"	"	"	4	22	18	5	5	0.0652	1550	1490	1480	1400	1490	1380	-55	-50	-50	927	1 3/4	55.7
3	No.3	200	100	22	19	21	26	22	24	"	"	"	8	16	14	7	7	0.0019	212	215	215	135	165	130	-50	-50	-50	109	5 1/2	80.2
	Bar.	300	250	22	16	20	23	20	22	"	"	"	7	14	13	5	5	0.0055	510	500	510	270	280	260	-75	-75	-75	242	4 1/2	37.2
	28.96	800	400	20	15	19	22	22	21	"	"	"	6	13	13	4	4	0.0130	850	890	850	510	500	500	-100	-100	-100	416	4 1/2	34.3
	Temp.	1100	550	19	15	19	20	20	20	"	"	"	6	13	12	4	4	0.0296	1090	1080	1090	640	640	620	-100	-100	-100	530	4 1/2	41.4
	77	1400	700	19	16	19	21	20	21	"	"	"	5	12	11	4	4	0.0473	1450	1380	1400	850	800	800	-125	-125	-125	701	4 1/2	40.8
4	No.4	200	200	19	16	20	22	18	20	"	"	"	5	17	9	2	2	0.0031	290	290	290	260	280	270	25	30	25	196	1 3/4	24.1
	Bar.	300	300	17	16	17	18	17	17	"	"	"	6	12	10	2	2	0.0061	850	830	840	810	820	800	-100	-100	-100	517	1 3/4	54.1
	29.00	800	800	12	12	12	15	13	14	"	"	"	4	10	8	2	2	0.0083	1370	1340	1360	1320	1330	1300	-125	-125	-125	849	1 3/4	25.73
	Temp.	1100	1100	11	11	11	15	13	14	"	"	"	5	8	7	2	2	0.0128	1990	1930	1940	1860	1950	1860	-130	-150	-150	1231	1 3/4	25.15
	74.8	1400	1400	13	11	13	13	12	13	"	"	"	4	8	7	2	2	0.0290	2600	2420	2490	2260	2380	2320	-200	-200	-200	1540	1 3/4	29.5
5	No.5	200	133	34	27	33	36	34	35	"	"	"	4	24	22	5	5	0.0028	246	230	245	240	260	240	-30	-30	-30	131	3 1/2	118.2
	Bar.	300	333	31	27	31	37	34	33	"	"	"	4	23	21	5	5	0.0173	650	640	650	480	480	480	-60	-60	-60	336	3 3/8	108.2
	28.93	800	533	29	26	29	32	30	31	"	"	"	5	24	21	6	6	0.0484	1020	1010	1020	670	680	650	-80	-80	-80	534	3	122.0
	Temp.	1100	733	26	24	27	30	29	30	"	"	"	6	22	19	6	6	0.0890	1480	1420	1440	950	960	950	-100	-100	-100	767	3	124.
	77.0	1400	933	30	27	30	34	31	32	"	"	"	4	24	22	5	5	0.1454	1890	1850	1880	1270	1270	1250	-145	-145	-145	997	3 3/8	125.3
6	No.6	200	100	26	20	25	32	30	32	"	"	"	6	29	27	3	3	0.0016	225	225	230	130	130	130	-45	-45	-45	109	6	67.0
	Bar.	300	250	25	23	25	32	29	32	"	"	"	5	22	20	5	5	0.0122	370	330	370	210	215	215	-50	-50	-50	242	6	76.7
	29.16	800	400	23	19	23	27	24	26	"	"	"	5	16	14	5	5	0.0311	940	930	940	250	260	250	-65	-65	-65	375	6	81.5
	Temp.	1100	550	26	22	25	32	29	32	"	"	"	5	16	14	6	6	0.0610	1310	1280	1300	270	270	270	-80	-90	-90	496	6	84.5
	76.0	1400	700	25	22	25	30	28	30	"	"	"	5	15	13	6	6	0.0998	1690	1660	1680	300	300	300	-125	-125	-125	717	6	85.4
7	No.7	200	200	29	16	29	24	19	25	34	27	36	6	18	17	6	6	0.0020	220	218	220	225	225	225	170	200	170	208	1/8	83.7
	Bar.	300	300	20	16	21	20	16	21	26	23	30	4	17	16	6	6	0.0069	530	520	520	540	530	530	280	400	290	440	1/4	46.2
	29.25	800	800	21	15	22	25	19	22	27	22	30	4	17	16	5	5	0.0190	870	850	850	860	860	860	500	800	550	779	1/4	48.7
	Temp.	1100	1100	24	19	24	26	20	23	28	20	30	4	17	16	6	6	0.0370	1170	1140	1120	1140	1110	1130	830	1130	830	1070	0	51.2
	74.0	1400	1400	18	15	19	26	20	24	27	19	30	5	17	16	8	8	0.0597	1520	1510	1500	1500	1550	1620	1020	1510	1150	1427	0	51.0
8	No.8	200	200	16	13	12	10	10	9	10	12	15	3	12	10	3	3	0.0008	190	208	208	210	210	195	202	205	205	203	1/4	33.9
	Bar.	300	300	13	12	10	11	10	10	12	11	13	4	12	11	5	5	0.0065	490	510	530	560	550	490	460	500	480	508	1/4	44.1
	28.92	800	800	12	10	11	12	10	10	11	11	15	3	11	10	5	5	0.0162	760	850	880	910	900	840	760	840	830	838	1/4	42.9
	Temp.	1100	1100	13	9	10	13	9	11	10	10	14	3	11	10	5	5	0.0251	990	1140	1250	1240	1170	1060	1020	1100	1120	1121	1/4	39.3
	73.0	1400	1400	15	9	11	10	10	11	10	10	12	2	10	9	5	5	0.0419	1360	1350	1490	1360	1330	1320	1320	1340	1300	1423	0	36.2
9	No.9	200	133	4	6	4	3	3	5	6	9	1	5	4	6	6	6	0.0000	140	175	170	175	175	150	155	165	165	163	0	0.0
	Bar.	300	333	8	8	9	11	6	6	11	11	14	3	9	7	6	6	-.0010	310	360	380	430	420	350	240	310	260	340	1/4	-6.7
	28.89	800	333	8	9	9	11	7	6	12	11	14	3	9	8	7	7	-.0037	570	710	680	720	730	570	310	440	400	572	1/4	-9.7
	Temp.	1100	733	9	9	10	11	9	8	11	11	16	4	9	8	7	7	-.0067	760	870	920	940	940	870	570	780	620	802	1/4	-9.3
	72.0	1400	933	9	9	10	11	8	9	9	10	16	4	8	7	7	7	-.0114	960	1160	1220	1230	1230	1000	600	850	860	1012	1/4	-9.7
10	No.10	200	200	19	18	20	20	16	19	20	16	20	6	18	13	8	8	0.0016	190	205	205	215	220	210	195	205	210	204	0	63.0
	Bar.	300	300	11	11	11	12	9	12	11	12	12	5	11	9	8	8	0.0037	470	510	500	550	550	490	460	490	490	500	0	39.5
	28.72	800	800	11	8	9	9	8	8	9	8	8	5	8	8	8	8	0.0110	730	830	780	860	860	770	720	810	830	778	0	31.9
	Temp.	1100	1100	7	7	8	9	6	8	8	8	9	4	7	6	7	7	0.0213	980	1120	1100	1160	1170	1010	1020	1120	1110	1088	0	32.7
	83.0	1400	1400	9	6	8	8	5	8	8	7	7	4	8	6	6	6	0.0339	1230	1320	1340	1510	1360	1440	1420	1460	1400	1389	0	29.6

Stack heads Nos. 20 and 21 were similar to Nos. 11 and 16 except for the addition of turning vanes. In the stack with the 14-in. x 6-in. opening five turning vanes were used and in the stack with 14-in. x 9-in. opening six turning vanes were used all equally spaced. The inside radius of the vanes was 2 in. and the outside radius was 1 in. The turning vanes completely eliminated the reverse flow which extended for almost 2 in. of height in No. 11 and over 3 in. in No. 16. Along with this elimination also went the tendency for higher velocities at the top third of the opening. In fact, the particular installations made resulted in slightly higher velocities at the bottom than at the top. This is probably due to the trailing edges of the vane having a slight dip with the horizontal. A radius on the throat of the stack head equal to that of the outside of the turning vanes and a radius on the back corner of the stack head equal to that on the inside of the turning vanes should result in more perfect distribution. It is evident from the results with stack heads Nos. 20 and 21 that turning vanes in square turns give excellent performance.

The directions of the issuing air stream are tabulated in Columns 5 to 18 in Tables 2 and 3 for all velocities and are shown graphically in Figs. 5 and 6 for stack velocities of 500 and 1100 fpm.

Space limitations permit only a brief summary of observations made to determine discharge angles. Results indicate that the discharge angle decreases with increase in face opening for stack heads Nos. 1, 2 and 3. Discharge angles are less for a square throat as indicated in Nos. 1 and 4 than in a rounded throat stack head. With higher velocities Nos. 4 and 5 showed a lower angle of discharge. Stack head No. 6 in the same series does not conform due to the greater face to throat dimension. With a change from a 3-in. to 6-in. throat radius only a slight lowering of discharge angle can be noted in Nos. 1 and 7. Stack heads Nos. 8, 9 and 10, equipped with splitters, show a discharge angle about half of that for corresponding stack heads Nos. 1, 2 and 7. A comparison of Nos. 15 and 17 equipped with cushion chambers with those of Nos. 11 and 16, which are plain, show no appreciable effect on discharge angle. Heads Nos. 11, 16 and 18 which are square turns indicate an increase in discharge angle from 20 to over 30 deg with increase in face height from 6 in. to 12 in. Rounded back stack heads Nos. 4 and 5 indicate an increase in discharge angle of 15 deg with change in face opening from 6 in. to 9 in. as compared to half that increase for the square turns for Nos. 11 and 16. Turning vanes added to the square stack heads Nos. 20 and 21 reduced the angle of discharge to slightly below the horizontal.

The static pressure at the base of the stack heads at the various stack velocities is given in Column 19 of Tables 2 and 3. The results are also shown graphically for various groups of stack heads in Figs. 7 to 12 inclusive. Column 31 of Tables 2 and 3 shows this static pressure at the base of the stack head, which is also the static pressure drop to the atmosphere, in per cent of the velocity head at the base of the stack head.

A comparison of the static pressure drops for five

Table 3—Results of Tests on Stack Heads Nos. 11 to 21

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		Stack Vel	Face Vel	Angle with Horizontal at Face — Degrees									mm Hg	At 12" Out — Degrees				Stack Head	Velocity — FPM										Nos from	SP VP
		FPM	FPM	1	2	3	4	5	6	7	8	9	Dev	Top	Bot	RS	LS	S.P.	1	2	3	4	5	6	7	8	9	Ave	IN UP	Ratio
11	No.11	200	200	19	17	20	26	20	21	Turbulent			6	16	14	6	6	0.0073	280	270	280	260	260	260	-10	-10	-10	172	1 1/8	307.2
	Bar.	500	500	20	14	16	22	20	20	"	"	"	5	16	15	6	6	0.0365	800	780	800	760	790	780	-60	-60	-60	501	1 1/8	331.3
	29.40	800	800	17	14	16	16	14	17	"	"	"	5	17	16	6	6	0.0911	1280	1260	1290	1240	1230	1240	-80	-80	-80	813	1 1/8	334.0
	Temp.	1100	1100	17	15	18	18	16	18	"	"	"	6	17	16	7	7	0.1706	1890	1840	1830	1730	1770	1730	-100	-100	-100	1160	1 1/8	231.9
	71.0	1400	1400	16	14	16	20	17	21	"	"	"	6	17	16	7	7	0.2750	2370	2280	2300	2280	2280	2250	-130	-130	-130	1486	2	230.5
12	No.12	200	200	21	15	19	21	16	20	"	"	"	5	15	14	5	5	0.0053	300	280	300	270	280	280	-10	-10	-10	186	1 1/8	230.1
	Bar.	500	500	21	15	19	18	16	19	"	"	"	6	15	14	6	6	0.0317	790	770	790	760	790	760	-50	-50	-50	500	1 1/8	213.3
	29.40	800	800	20	16	22	22	19	23	"	"	"	7	15	13	6	6	0.0863	1240	1240	1260	1230	1260	1230	-80	-80	-80	602	1 1/8	226.1
	Temp.	1100	1100	18	16	17	20	17	20	"	"	"	8	15	14	8	8	0.1660	1830	1800	1820	1790	1820	1700	-100	-100	-100	1171	2	231.0
	78.0	1400	1400	18	16	17	22	18	22	"	"	"	9	16	13	8	8	0.2700	2400	2310	2350	2220	2260	2230	-130	-130	-130	1687	2 1/8	232.0
13	No.13	200	200	17	13	17	20	17	18	"	"	"	6	13	12	6	6	0.0051	290	270	300	270	290	270	-10	-10	-10	184	1 1/8	211.9
	Bar.	500	500	18	13	17	20	16	21	"	"	"	6	14	12	6	6	0.0335	770	780	780	760	770	750	-30	-30	-30	502	1 1/8	221.8
	29.40	800	800	18	14	16	22	16	22	"	"	"	12	13	11	10	10	0.0905	1260	1280	1290	1240	1270	1230	-75	-75	-75	615	2	235.0
	Temp.	1100	1100	18	16	19	21	16	22	"	"	"	11	13	11	10	10	0.1610	1820	1800	1810	1670	1750	1640	-110	-110	-110	1129	2 1/8	221.5
	77.0	1400	1400	18	15	19	20	16	21	"	"	"	12	14	13	10	10	0.2720	2300	2290	2290	2240	2200	2230	-160	-160	-160	1461	2 1/8	231.0
14	No.14	200	200	22	16	21	21	20	22	"	"	"	7	1	15	6	6	0.0051	280	270	290	250	270	260	-10	-10	-10	177	1 1/8	216.1
	Bar.	500	500	20	14	19	19	17	20	"	"	"	6	17	14	6	6	0.0382	770	790	790	760	780	760	-40	-40	-40	503	1 1/8	235.0
	28.92	800	800	22	16	20	19	17	20	"	"	"	5	17	15	6	6	0.0964	1270	1320	1280	1260	1300	1230	-70	-70	-70	628	2	235.0
	Temp.	1100	1100	20	17	21	20	17	19	"	"	"	5	16	14	6	6	0.1774	1780	1850	1770	1720	1750	1730	-100	-100	-100	1144	2 1/8	249.0
	78.0	1400	1400	19	15	18	20	18	21	"	"	"	6	16	13	6	6	0.2920	2340	2360	2320	2210	2270	2200	-130	-130	-130	1482	2 1/8	232.7
15	No.15	200	200	20	17	20	21	19	21	"	"	"	5	17	16	5	5	0.0057	290	280	290	270	280	260	-10	-10	-10	182	1 1/8	241.8
	Bar.	500	500	19	13	19	20	16	19	"	"	"	5	17	15	5	5	0.0333	810	780	800	780	790	770	-30	-30	-30	516	1 1/8	226.0
	28.92	800	800	17	16	21	20	16	19	"	"	"	6	18	14	6	6	0.0873	1300	1240	1290	1220	1290	1240	-70	-70	-70	819	2	230.7
	Temp.	1100	1100	18	14	20	21	17	19	"	"	"	6	17	15	7	7	0.1625	1890	1810	1830	1730	1850	1790	-100	-100	-100	1108	2 1/8	227.8
	78.0	1400	1400	17	14	18	20	16	15	"	"	"	7	15	13	7	7	0.2730	2360	2280	2250	1900	2240	1950	-125	-125	-125	1400	2 1/8	238.0
16	No.16	200	133	21	20	24	28	30	28	"	"	"	9	22	21	6	6	0.0022	230	230	230	225	240	225	-25	-25	-25	145	3 1/8	92.3
	Bar.	500	333	21	20	23	26	26	26	"	"	"	9	20	19	8	8	0.0136	590	570	580	550	550	530	-60	-60	-60	343	3 1/8	105.0
	29.30	800	533	24	22	25	26	25	27	"	"	"	10	19	18	10	10	0.0430	970	950	980	880	870	860	-90	-90	-90	586	3 1/4	112.8
	Temp.	1100	733	23	22	26	28	26	25	"	"	"	10	20	19	11	11	0.0822	1320	1250	1330	1170	1150	1130	-110	-110	-110	780	3 1/4	114.2
	80.0	1400	933	25	22	25	27	24	26	"	"	"	10	21	19	11	11	0.1327	1800	1720	1800	1630	1600	1500	-130	-130	-130	1073	3 1/4	116.2
17	No.17	200	133	26	26	26	29	31	29	"	"	"	9	26	24	8	8	0.0021	235	240	235	230	240	230	-30	-30	-30	147	3 1/4	87.7
	Bar.	500	333	23	22	24	28	26	26	"	"	"	9	20	18	9	9	0.0162	590	570	580	510	560	500	-60	-60	-60	337	3 1/4	100.3
	29.24	800	533	22	18	23	26	24	23	"	"	"	9	26	23	10	10	0.0433	960	940	980	920	940	910	-80	-80	-80	601	3 1/4	118.1
	Temp.	1100	733	22	19	25	26	23	24	"	"	"	9	22	20	11	11	0.0860	1340	1250	1300	1170	1220	1190	-120	-120	-120	790	3 1/4	118.9
	77.0	1400	933	21	17	22	25	22	23	"	"	"	10	22	19	14	14	0.1403	1800	1650	1800	1660	1730	1600	-130	-130	-130	999	3 1/4	120.0
18	No.18	200	100	22	19	23	32	27	25	"	"	"	6	19	17	6	6	0.0016	170	190	185	180	180	175	-20	-20	-20	113	4 1/8	67.5
	Bar.	500	250	30	26	34	35	42	34	"	"	"	12	25	22	13	15	0.0097	480	470	490	350	410	360	-40	-40	-40	271	4 1/8	65.5
	29.35	800	400	29	23	30	39	36	35	"	"	"	9	26	22	10	10	0.0248	760	840	770	670	600	620	-60	-60	-60	453	4 1/8	62.5
	Temp.	1100	550	32	27	33	40	35	33	"	"	"	8	28	25	10	10	0.0463	1100	1110	1110	870	810	830	-90	-90	-90	648	4 1/8	64.6
	83.0	1400	700	30	27	31	41	39	35	"	"	"	9	27	24	11	11	0.0761	1380	1350	1380	1180	1150	1100	-130	-130	-130	794	4 1/8	62.6
19	No.19	200	200	18	18	20	26	21	24	21	28	30	12	21	20	7	7	0.0024	230	235	230	230	220	220	190	195	190	217	1/8	102.7
	Bar.	500	500	11	17	20	32	22	22	24	32	34	2	20	19	6	6	0.0038	520	640	660	520	550	500	470	280	360	493	1/8	94.7
	28.78	800	800	15	16	20	28	21	18	21	29	23	7	19	18	9	9	0.0337	840	910	920	870	900	870	810	550	580	806	1/8	90.3
	Temp.	1100	1100	12	16	21	30	21	18	21	31	20	10	22	20	12	12	0.0626	1440	1250	1240	1120	1180	1030	1030	850	1020	1098	1/8	88.9
	83.0	1400	1400	17	20	25	29	19	22	26	20	23	9	18	13	13	13	0.1000	1550	1500	1670	1520	1570	1530	1410	1400	1310	1499	1/8	87.5
20	No.20	200	200	0	-1	-1	-2	-4	-4	-1	-1	0	0	-4	-2	1	1	0.0010	203	209	210	210	210	200	195	210	205	206	0	42.4
	Bar.	500	500	-1	-3	-3	-3	-4	-4	-4	-4	-3	1	-2	-5	2	2	0.0049	440	500	500	520	530	480	470	500	500	493	0	33.4
	28.94	800	800	-2	-3	-3	-4	-4	-4	-3	-3	0	1	-2	-5	2	2	0.0162	750	790	810	840	840	800	760	890	830	806	0	43.1
	Temp.	1100	1100	-1	-3	-4	-5	-4	-3	-3	-3	-3	1	-2	-3	3	3	0.0300	990	1000	1080	1120	1110	1090	1070	1130	1130	1090	0	42.1
	79.0	1400	1400	-2	-4	-3	-3	-5	-4	-3	-2	-2	2	-3	-4	2	2	0.0487	1360	1370	1370	1440	1410	1420	1400	1480	1400	1406	0	42.2
21	No.21	200	133	3	4	6	0	-1	1	2	-1	0	4	2	-1	4	4	0.0003	130	130	125	155	160	155	145	130	150	144	0	12.9
	Bar.	500	333	7	6	6	-2	-3	-3	-4	-4	-3	2	1	-2	3	3	0.0002	240	230	240	360	360	350	360	380	360	319	0	1.4
	28.72	800	533	5	2	4	-4	-7	-4	-3	-6	-3	0	0	-6	3	3	-0.0006	360	320	350	660	650	570	570	680	630	532	0	-1.6
	Temp.	1100	733	6	3	2	-3	-4	-3	-3	-3	-4	1	-2	-8	2	2	-0.0020	560	520	530	850	940	760	820	960	950	766	0	-4.1
	77.0	1400	933	4	0	3	-2	-5	-3	-6	-6	-7	1	-2	-7	2	2	-0.0057	710	550	670	990	1170	980	1040	1230	1210	940	0	-4.9

heads with 14-in. x 6-in. outlets is shown in Fig. 7. The highest pressure drop, 0.3 in. at 1400 fpm, was found with No. 4, a short radius turn with a square throat. Fig. 8 shows the effect on the static pressure drop with the addition of turning vanes and splitters to the plain stack heads Nos. 1, 7 and 11, all with 14-in. x 6-in. face opening. In every case a reduction was experienced.

Expanding stack heads with a 14-in. x 9-in. face opening are shown on Fig. 9. The same relative positions as to drop in static pressure are found for rounded and square back heads Nos. 5 and 16 as for the two with 14 in. x 6-in. face opening, Nos. 4 and 11.

The change in static pressure at the base of the stack head with increase in face opening is shown in Fig. 10 for short radius heads, in Fig. 11 for square-throated, rounded back heads and in Fig. 12 for square heads. In each case, an increase in face opening resulted in a lower static pressure at the base of the stack.

In all of these stack head tests the total energy of the air stream at the base of the head is used up in resistance through the turn and in resistance in being delivered out into the room air. The algebraic sum of the static and velocity pressures at the base of the stack head gives a measure of this energy. The addition of these energies at 1400 fpm for the short radius turns, Nos. 1 and 8, indicates that the splitters reduce the energy to 74 per cent. With the longer radius turns, Nos. 7 and 10, the reduction is only to 90 per cent and with the expanding heads, Nos. 2 and 9, the addition of splitters reduced the energy to 58 per cent. Similarly for the square type stack heads with 14-in. x 6-in. face opening, Nos. 11 and 20, turning vanes reduced the energy to 42 per cent. In the case of the square type with a 14-in. x 9-in. face opening, Nos. 16 and 21, the energy was reduced to 44 per cent by the addition of turning vanes.

Conclusions

In most stack heads whether of the square or round type the air left at angles varying from 20 to 35 deg with the horizontal. The angle with the horizontal was less for stack heads with square throats than for those with an inner radius. A change from a 3-in. to a 6-in. inner radius only lowered the angle slightly. A greater face to throat dimension lowered the discharge angle. A larger face opening height resulted in a greater angle of discharge. This increase with an increase in opening height from 6 in. to 9 in. was twice as large with a rounded back stack head as with a square back stack head.

In most stack heads an area of reverse flow was found in the lower section of the face opening. The throat or inner radius was very important in determining the extent of this reverse flow, being largest with a square throat, less with a 3-in. inner radius and negligibly small with a 6-in. inner radius. The outer radius had prac-

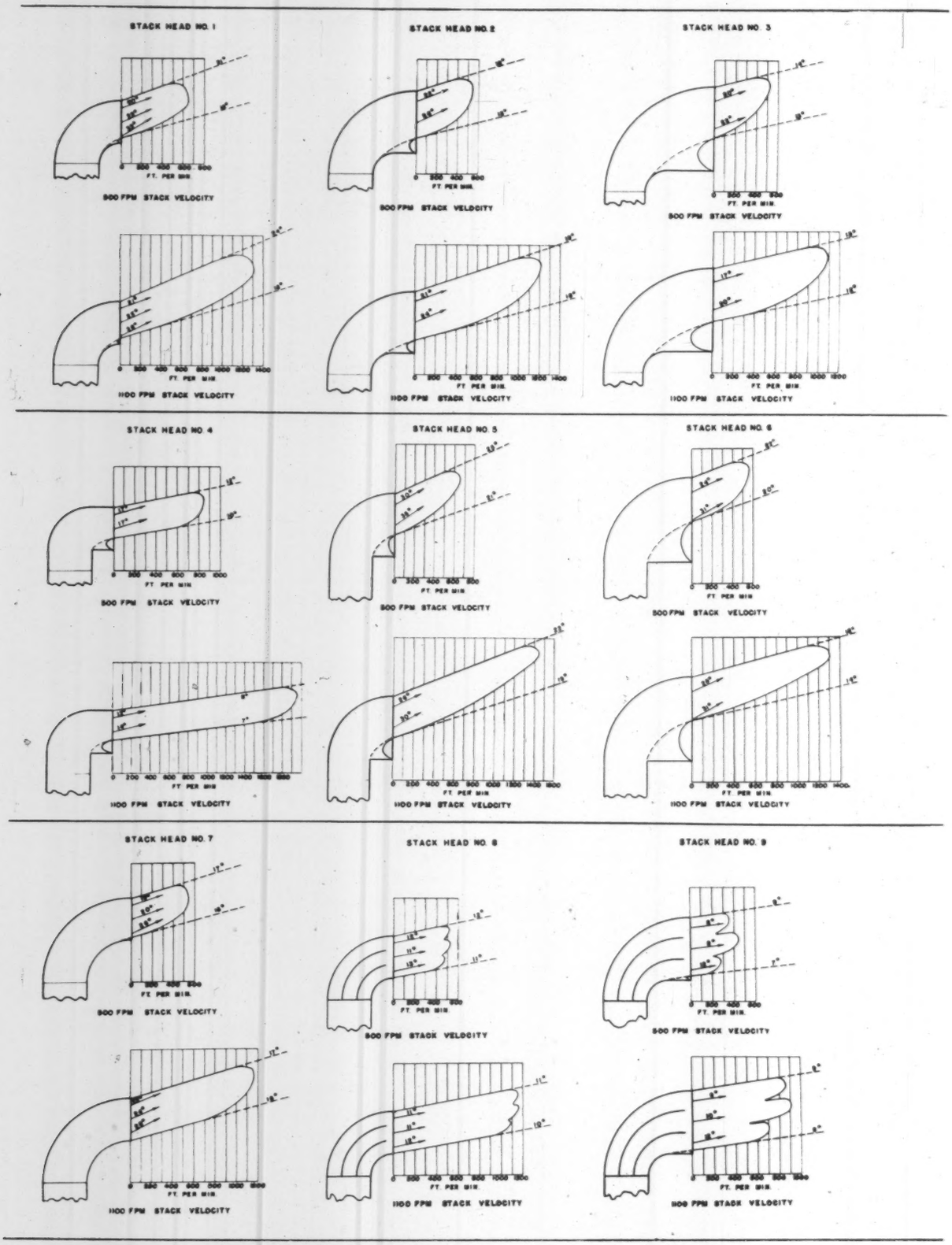

Fig. 5—Velocity and direction diagrams for stack heads Nos. 1 to 9

tically no influence on this reverse flow area. The area of reverse flow increased almost directly with the face opening height with a given shape of stack head.

Large reverse flow area in general was associated with high angle of discharge and a large variation in face velocities.

Cushion chambers placed above square type stack heads had no effect on the distribution characteristics. The use of two splitters in the round type stack heads lowered the discharge angle with the horizontal to about one-half that of the plain fitting, made the face velocity quite uniform, and caused the reverse flow area to disappear or to become very small. The characteristics were changed to those of longer radius turns. Little differ-

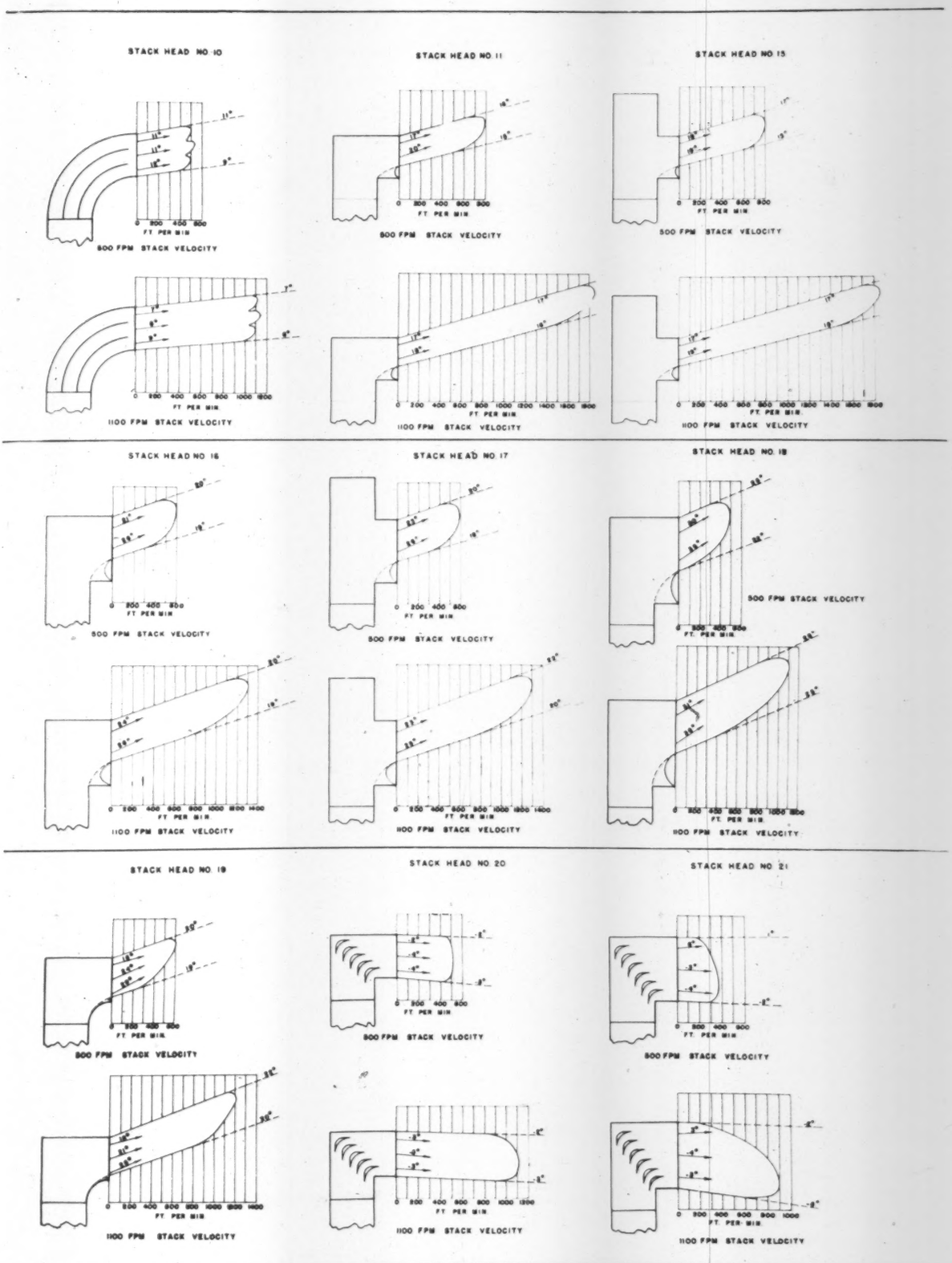

Fig. 6—Velocity and direction diagrams for stack heads Nos. 10 to 21

ence was found in the results when applied to the short or long radius turn. The use of five or six turning vanes with a 1-in. outer radius and a 2-in. inner radius resulted in good distribution as to direction, uniformity of face velocity and absence of reverse flow area.

The highest pressure drop was found with the square-throated rounded-back type. The square type showed only slightly less drop. On either of these the substitution of a 3-in. inner radius for the square throat caused the pressure drop to become very much less. The use of a 6-in. inner radius resulted in a further decrease in pressure drop. Splitters in stack heads with short radii and turning vanes in square stack heads lowered the pressure drop below that of the long radius stack head

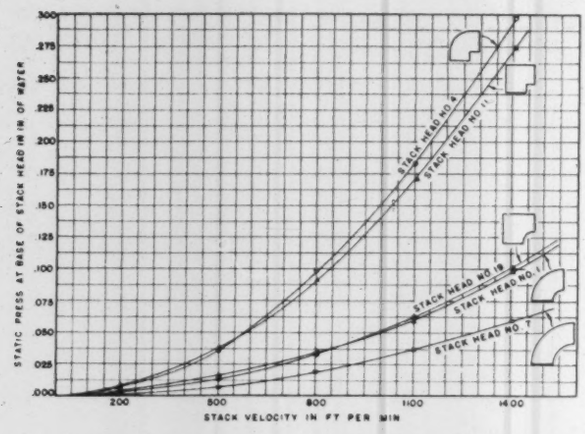
STATIC PRESS AT BASE OF STACK HEAD IN IN OF WATER
STACK VELOCITY IN FT PER MIN
STACK HEAD NO 4
STACK HEAD NO 11
STACK HEAD NO 18
STACK HEAD NO 1
STACK HEAD NO 7

Fig. 7—Static pressure at base of stack head for various non-expanding stack heads

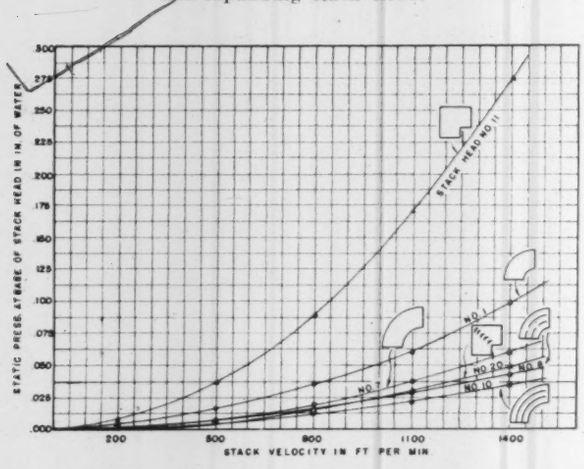

Fig. 8—Effect of turning devices on static pressure at base of stack heads of non-expanding type

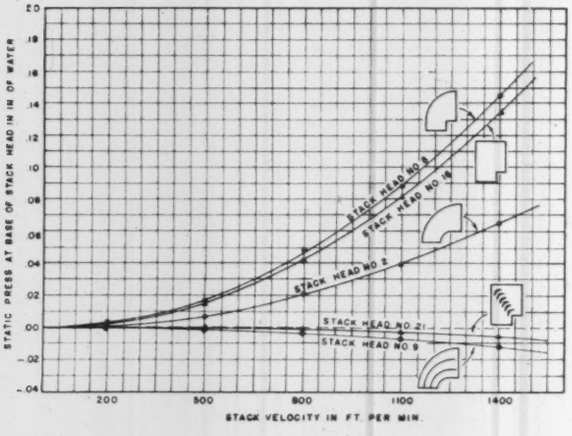
STATIC PRESS AT BASE OF STACK HEAD IN IN OF WATER
STACK VELOCITY IN FT PER MIN
STACK HEAD NO 8
STACK HEAD NO 18
STACK HEAD NO 2
STACK HEAD NO 21
STACK HEAD NO 9

Fig. 9—Effect of turning devices on static pressure at base of stack heads of expanding type

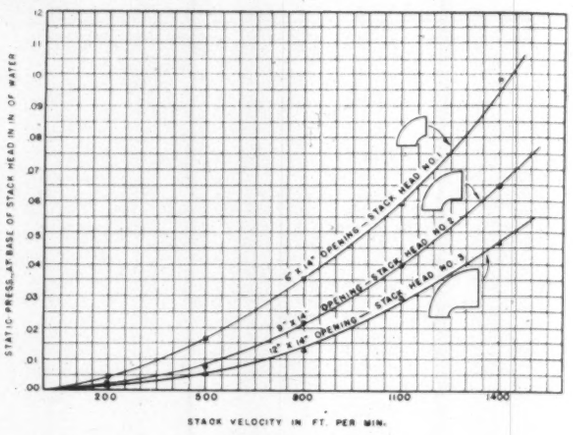
STATIC PRESS AT BASE OF STACK HEAD IN IN OF WATER
STACK VELOCITY IN FT PER MIN
6" X 14" OPENING — STACK HEAD NO 1
9" X 14" OPENING — STACK HEAD NO 2
12" X 14" OPENING — STACK HEAD NO 3

Fig. 10—Variation of static pressure at base of stack heads of rounded type with the face opening

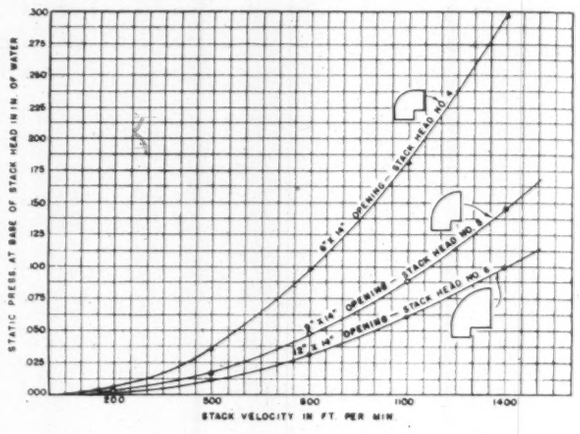
STATIC PRESS AT BASE OF STACK HEAD IN IN OF WATER
STACK VELOCITY IN FT PER MIN
6" X 14" OPENING — STACK HEAD NO 4
9" X 14" OPENING — STACK HEAD NO 5
12" X 14" OPENING — STACK HEAD NO 6

Fig. 11—Variation of static pressure at base of stack heads of square-throated rounded-back type with the face opening

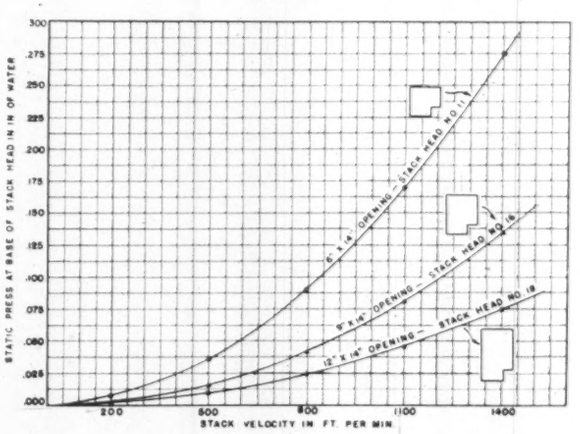
STATIC PRESS AT BASE OF STACK HEAD IN IN OF WATER
STACK VELOCITY IN FT PER MIN
6" X 14" OPENING — STACK HEAD NO 17
9" X 14" OPENING — STACK HEAD NO 18
12" X 14" OPENING — STACK HEAD NO 19

Fig. 12—Variation of static pressure at base of stack heads of square type with the face opening

tested. Splitters in the long radius stack head reduced the pressure drop below that for the square and short radius types with turning devices.

When applied to expanding stack heads the turning devices resulted in lowering the static pressure at the base of the stack head below atmospheric pressure. This was due to the uniformly low velocity over the whole discharge area and the interchange of kinetic and pressure energies between the inlet and outlet of the stack head.

The sum of the static pressure and the velocity pressure at the base of the stack head was considered to give a measure of the energy required to make the turn and to enter the atmosphere where all energy in these two forms is dissipated. In square type stack heads the addition of turning vanes dropped this energy to about 45 per cent, considering the energy required in the plain fitting as 100 per cent. The application of splitters to the long radius turn reduced the energy to 90 per cent and to 74 per cent with the short radius turn. With an expanding head this measure of energy with the application of splitters was reduced to 58 per cent.

The application of splitters and turning vanes improved the performance of stack heads materially.

Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS is located

Seasonal Variation in Reactions to Hot Atmospheres

By F. C. Houghten* (*MEMBER*), A. A. Rosenberg** and M. B. Ferderber, M.D.*** (*MEMBER*)
Pittsburgh, Pa.

THE Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS has been interested in a study of the physiological reactions of persons to hot atmospheres since 1922, and a number of reports on this work have been published in the TRANSACTIONS of the Society. During 1938 the study was carried on under the Technical Advisory Committee on Air Conditioning in Industry, consisting of A. E. Stacey, Jr., *Chairman*, Philip Drinker, Dr. Leonard Greenburg, H. P. Greenwald, A. M. Kinney, J. W. Kreuttner, L. L. Lewis, Dr. W. J. McConnell, Dr. C. P. McCord, P. A. McKittrick, Dr. R. R. Sayers, Dr. Charles Sheard, C. Tasker and R. M. Watt, Jr. The work was directed toward a study of the reactions of workers to hot atmospheres in industry in order to develop data of value in applications of air conditioning in industry. A comprehensive report[1] of this work was presented at the 1939 Annual Meeting, giving such physiological reactions as: rise in body temperature, increase in pulse rate, increase in leucocyte blood count, decrease in vital capacity, degree of perspiration, and the feeling of warmth, after the lapse of certain periods of work in various hot atmospheres.

Since all of the data published in the earlier report were collected during the summer, the work during 1939 was directed toward a study of the reactions of workers to similar atmospheric conditions during other seasons of the year. The results of this phase of the study, made during the winter, spring and summer seasons, are contained in this paper.

The test procedure followed closely that of the earlier study. The same subjects or others of approximately the same physical and mental make-up as those participating in the previous work were used, and included seven college students ranging in age from 17 to 22 years. Each subject was given a medical examination to see if his body temperature, pulse, blood pressure (both systolic and diastolic), and basal metabolism were normal. The average value for this latter determination had been found in the past to be approximately 40 large calories per square meter per hour (or 288 Btu per hour for the average sized adult male), and no subject was selected for these tests if his basal was found to be far different from this norm.

With few exceptions, four subjects participated in each of these tests. Usually five days of hot tests were given in sequence, then a series of five days of cooler tests. Some alternation of hot and cool tests was made over the period of a week in order to determine the effect of acclimatization due to frequent exposure to a hot or cool condition. Considerable data were collected during the months of February and March, a smaller amount during April, and a still less amount during the first part of August of the past summer.

As in the earlier study, the subjects were seated at

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[1]Air Conditioning in Industry, by W. L. Fleisher, A. E. Stacey, Jr., F. C. Houghten, and M. B. Ferderber, M. D. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, February, March and April, 1939).

Presented at the 46th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Cleveland, Ohio, January, 1940.

rest in a control room for about 45 min in order to permit their various physiological reactions to approach a norm, before entering the psychrometric room where they engaged in their specified activity for three hours. This activity consisted of the light work connected with the operation of the "chance machine," as described in the previous paper. Metabolisms were taken during the three hour test period to determine that the rate of work was the same as during the tests previously reported. This light work, requiring that the subject be attentive and on his feet about three-quarters of the time, resulted in an average metabolic rate of 76 large calories per square meter per hour (or 546 Btu per hour for the average sized adult male). During the entire rest and test periods the subject was required periodically to observe and record his various physiological reactions, such as body temperature, pulse rate, vital capacity, degree of perspiration, and feeling of warmth. The medical observer at less frequent intervals took observations of each subject's leucocyte count and blood pressure. The subject was weighed nude at the beginning of the test in the control room as well as after the test in order to obtain a measure of the perspiration loss.

In some of the later tests, readings of rectal temperature and leucocyte count were made after the subject had completed his three hours of test and had been again in the control room for a one hour period. The purpose of this was to obtain an indication of how quickly the body returned to normal after being relieved from the hot atmospheric condition. The atmospheric condition maintained during the period of tests was varied throughout the range of 74 ET to 92 ET; and the relative humidity was maintained at either 60 or 90 per cent, the greater number of tests being run at the lower humidity condition.

Test Data and Results

Tabulations and plots of the various physical and physiological reactions were made for each subject for each individual test; and from these data, summary curves were made up to indicate the general trends and pertinent conclusions. In Fig. 1 is shown the relation between the rise in body temperature above normal in degrees Fahrenheit and the effective temperature of the air condition; the filled-in data points being for 90 per cent relative humidity and the others for 60 per cent. The lower curve with no data points is taken from the previous report and represents the average for 60 and 90 per cent relative humidities. The points indicated by small circles are data taken during the months of February and March and are referred to as *Winter* data; the few points represented by triangles are for August 1939 and serve to corroborate to a small extent the data observed during the previous summer; and the small squares are used to represent data taken during April, a transition month between winter and summer.

It is readily seen from the curve for the February and March data that a person has a greater rise in body temperature when exposed to the same hot atmospheric environment during the winter than is realized during the summer. The transition curve for April which falls between the summer and winter curves serves to indicate that the body undergoes some progressive change in acclimatizing itself during changes of seasons of the year. Whereas the summer curve for the rise in body temperature increases from 0 deg to about 1.3 deg through the range of effective temperatures of 78 to 91, the winter curve increases from 0.75 deg to 1.65 deg; that is, at the lower effective temperature the rise is 0.73 deg higher during the winter, while it is only 0.35 deg or less than half as much higher at the greater effective temperature. This indicates that when the body is exposed to high indoor effective temperatures, acclimatization would have but little effect in regulating the body temperature. The fact that all three curves appear to be converging at the higher effective temperatures indicates that acclimatization has little effect at these extreme conditions of indoor effective temperature.

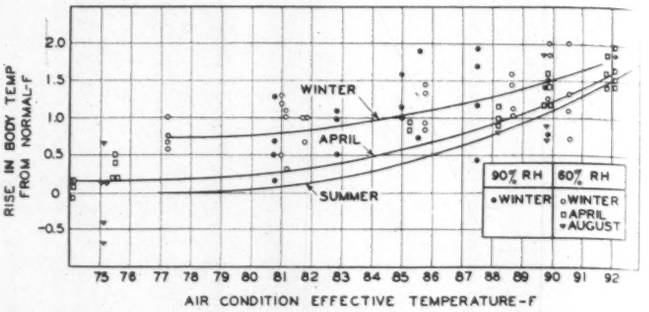

Fig. 1—Relation between rise in body temperature and effective temperature of indoor air condition at 60 and 90 per cent relative humidities, for summer, April and winter

Another very significant fact is arrived at by closely examining and comparing the summer and winter curves. It can be seen that the 1.0 deg temperature rise ordinate line intersects the winter curve at approximately 84.5 deg ET, whereas it intersects the summer curve at 89.5 deg ET. That is, the abscissae difference between the summer and winter lines at this 1.0 deg body temperature rise is 5 deg ET, or the same difference that occurs between the optimum summer and winter comfort conditions of 71 and 66 deg ET, respectively.

In order to furnish an indication of how well the body responds in returning to normal temperature after being relieved from a hot atmospheric condition to one of fairly ideal condition, one day's temperature data have been plotted in Fig. 2. Curves are shown for each of four subjects participating in the test during which the condition in the control room was approximately 73 deg ET; and a condition of 88 deg ET and a relative humidity of 60 per cent were maintained in the test room. This figure shows how each subject's temperature was allowed to reach equilibrium during the one hour in the control room prior to entering the test chamber; then during intervals in the test room, temperatures were recorded to indicate how rapidly and to what extent the body temperature increased. The average increase for three hours occupancy on this day was approximately 1.0 deg. After the subjects returned to the control room and remained at rest, all the body temperatures tended to return to normal; the average of the body temperatures was found to be only 0.2 deg above normal at the end of an hour of recuperation, an average drop of 0.8 in an hour. Likewise, in all other days of test the body was found to recuperate quite well after an hour rest in the control room, for in no instance did any subject's body temperature fail to return to within 0.4 deg of normal even though the body temperature had risen 2.0

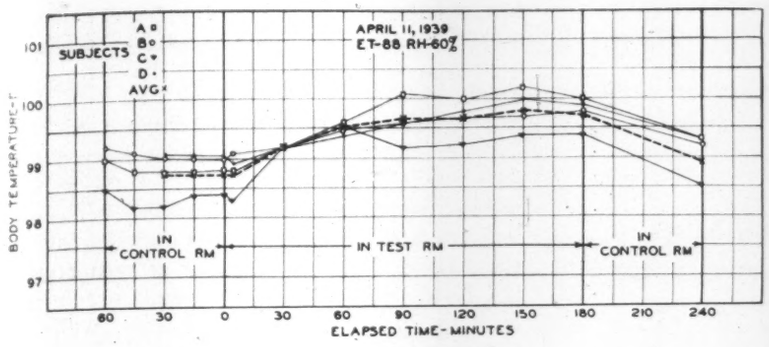

Fig. 2—Relation between rise in body temperature and exposure in control and psychrometric rooms

deg above normal after three hours exposure in the hot condition.

The increase in pulse rate above normal in beats per minute for all subjects after three hours exposure in all tests is plotted against effective temperature in Fig. 3, data for both 60 and 90 per cent relative humidity tests being included. These show to very good advantage, in a manner similar to Fig. 1, that acclimatization has a very definite effect on a person's reaction to indoor atmospheric conditions. At the lower effective temperatures the winter curve is displaced an appreciable amount above the summer pulse curve, with the April transition curve falling between the two and the three tending to run together at some high atmospheric condition.

The new leucocyte count data indicate that the summer curve would move slightly upward and to the left for winter months. There is shown in Fig. 4 for each of four subjects, as well as for the average value, the increase in the leucocyte count of the blood in white cells per cubic millimeter during three hours in the hot atmospheric condition, and the later decrease after the subjects' return to the control room. In no day of test did any subject's count fail to return toward normal, but it was found that usually one hour was insufficient time to bring the count completely to normalcy; that is, in most instances the count dropped only a little more than halfway back to the initial value.

The ability of the human body to adjust itself to changes in environment is a very important physiologic factor. This flexibility is well illustrated in a comparison of reactions not only to high temperatures but also to invading disease. In fever therapy research, it has been shown that long frequent exposures to hot atmospheres produce some changes in leucocyte response. The first treatments produce a distinct rise in white blood cells, but this rise may be considerably reduced or absent in successive treatments if the interval elapsing between treatments is insufficient.

While this explanation may be theoretical it is proposed as probable that there is a state of exhaustion or fatigue of the hemopoetic system which produces the white cells so necessary for protection against invading infection.

This explanation may be augmented by knowledge of what occurs to a person suffering from a chronic infection. At this point one must consider also the temperature mechanism that is involved. If a person develops an infection, his natural defensive response is characterized by a rise in body temperature and leucocytes. If the infection becomes chronic, there is less rise in either until eventually the count may be numerically normal and the temperature shows only the diurnal variation. Should this condition exist for some time and a more fulminating infection, such as pneumonia, invade the body, the failure of those necessary elements renders the body less effective against the illness.

Exposure of workers to high effective temperatures may produce the same changes if continued over long periods without some respite, in the form of cool surroundings as is experienced during the winter months. The rise in body temperature (Fig. 1) demonstrates this difference and, if a greater mass of summer data were available, one might expect to find the same tendencies in the leucocyte change. Another illustration is shown by the seriousness of so called "summer pneumonia" despite the fact that patients may receive the same treatment as during the pneumonia seasons. The stormy course and failure of therapeutic measures, in some measure, may be traced to the exhaustive state of the protective temperature and leucocyte rise due, presumably, to acclimatization.

From workers who have spent long periods in certain very hot climates, there is evidence to show that the failure of physiologic defense against infections is directly proportional to the time spent in the hot area. If true, one might conclude that the constant existence in extremely hot environments might produce a condition in the body where both temperature and white blood count may fail to increase as a defense measure.

This entire subject of temperature rise and increase in leucocyte count, and their significance in health and in disease make it highly important that active laboratory investigation of the subject be pressed forward.

No new data are given for vital capacities, blood pressures, weight losses, since these reactions show no pronounced change over those observed during the summer.

Summary

From the data presented in this paper it is indicated that a person's acclimatization to atmospheric environments during different seasons of the year not only affects his desire for some higher or lower effective temperature condition, but also affects certain physiological reactions. That is, both his body temperature rise and pulse rate increase are greater during the winter than during the summer upon being exposed to the same high

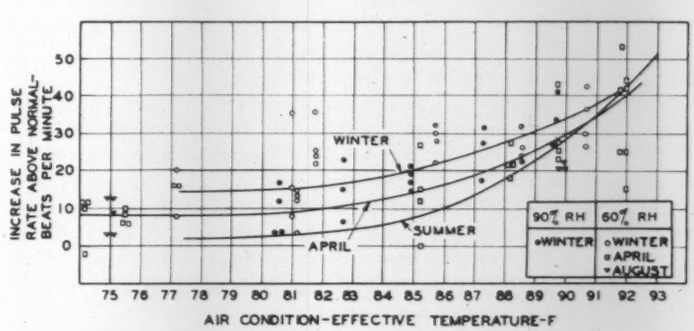

Fig. 3—Relation between increase in pulse rate in beats per minute and effective temperature of indoor air condition at 60 and 90 per cent relative humidities, for summer, April and winter

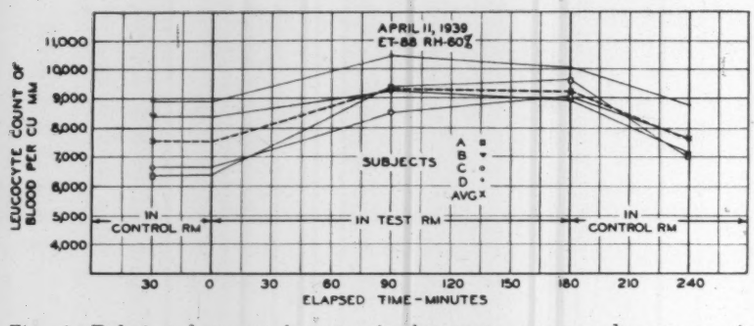

Fig. 4—Relation between increase in leucocyte count and exposure in control and psychrometric rooms

indoor effective temperature for the same period of time. Moreover, the body appears to undergo a progressive change in acclimatization with change in seasons; for pulse rate increase and temperature rise data during spring show a transition period between winter and summer, the rises being greater than for summer but less than for winter. The charts presented in this paper show also that acclimatization has but little effect at the higher effective temperature in regulating body reactions such as temperature rise and pulse increase; at some quite high effective temperature condition acclimatization would probably have no effect at all.

The sample curves for recovery of body temperature and leucocyte count after a subject has been relieved from a hot atmospheric condition to one of a comfortable environment indicate that the body returns quite rapidly toward normal. After one hour of recuperation, the body temperature was found to return at least to within 0.4 deg of normal; while the leucocyte count was found to return more than halfway to its initial control room value.

Acknowledgment

The authors are indebted to Dr. T. Lyle Hazlett and his Department of Industrial Hygiene, School of Medicine, University of Pittsburgh, for valuable counsel in connection with the physiological aspects of the study, and to Clara Waldinger, M. D., who made the blood counts and aided in other physiological observations.

Drs. Giesecke and Arendtz Massachusetts' Guests

December 19, 1939. The regular monthly meeting of the Massachusetts Chapter of the Society was held jointly with the *American Society of Refrigerating Engineers* at the Massachusetts Institute of Technology, Cambridge, with 50 members and guests in attendance for supper which was served at the Walker Memorial Cafeteria preceding the meeting. A sound film entitled "Flow" was shown immediately after supper.

The speaker of the evening, G. F. Begoon, gave an interesting talk on the electrical precipitator for air cleaning. Mr. Begoon outlined the research developments and the construction and operation of this equipment, which proved extremely interesting to the 100 members and guests present.

November 21, 1939. The November meeting of the Massachusetts Chapter was held jointly with the Air Conditioning Bureau in the Faculty Dining Room, Walker Memorial, Massachusetts Institute of Technology, Cambridge. Dinner was served at 6:30 p. m. and 65 members and guests attended.

About 95 were present for the meeting, at which First Vice-Pres. F. E. Giesecke and Dr. Herman F. Arendtz, staff economist, U. S. Business Service, were guest speakers. Dr. Arendtz talked about business conditions expected during the coming year and openly admitted that because of so many prevailing forces, it became necessary for him to climb recklessly out on a limb, which he apparently was quite willing to do. He had previously addressed the Air Conditioning Bureau and predicted the business trend for 1939 with very fine results, but primarily because of the war situation and the coming presidential election, he made this prediction for next year with numerous "if this happens then this will be so."

Professor Giesecke gave a very interesting talk on radiant panel heating, illustrated by a number of slides showing buildings in which this type of heating had been used, and commented on the data which have been collected. The talk began with a brief discussion of radiation from a molecular and spectrum analysis showing primarily the effect in the infra-red portion of the spectrum and some of the fundamental laws of radiation, conduction and convection. Professor Giesecke explained the methods of installation now in use and said that there was a great deal of work needed before this type of system could be used effectively and the results correctly predicted.

October 6, 1939. The October meeting of the Massachusetts Chapter was held jointly with the Harvard Engineering Societies at Pierce Hall, with Prof. Philip Drinker, Harvard School of Public Health, in charge.

The guest speaker was Lt. Commander Charles Monsen, who gave a very interesting semi-technical illustrated talk on the raising of the Squalus and the development of the rescue chamber used in the diving operations.

Houghten and Lewis Address Minnesota Meeting

December 4, 1939. In order to conform with the dates set for the Air Conditioning Conference sponsored jointly by the Minnesota Chapter and the University of Minnesota, the December meeting was advanced one week. The meeting was called to order at dinner by Pres. F. C. Winterer, at the Center for continuation study at the University, and was attended by 86 members and guests. After a few brief remarks by the president the meeting was turned over to Prof. F. B. Rowley, director, experimental engineering laboratory at the University, who introduced the Conference faculty members, D. W. Nelson, professor of steam engineering, University of Wisconsin, who, as one of the Board of Governors of the chapter, extended greetings and best wishes from the Wisconsin Chapter; R. E. Backstrom, chairman of arrangements for the Conference; Seichi Konzo, research professor, University of Illinois, who brought greetings from the Illinois Chapter and added a few comments in his own inimitable manner.

The meeting was then adjourned and moved in a body from the dining room to a more comfortable room to enjoy the speakers of the evening. Professor Rowley introduced F. C. Houghten, director of the Society's Research Laboratory at Pittsburgh, who spoke briefly on the present activities of the Laboratory and its future prospects.

The guest speaker of the evening, S. R. Lewis, consulting engineer, Chicago, and past president of the Society, was then introduced by Professor Rowley. Mr. Lewis proceeded in his own way and related a number of his experiences with heating and air conditioning installations and illustrated some of the pitfalls into which the more inexperienced engineer might fall unawares. Mr. Lewis' talk was both highly educational and amusing and brought forth a lively discussion, which both Mr. Lewis and his audience thoroughly enjoyed.

Research Committee Members Elected for Three Years

Philip Drinker was born in Haverford, Pa., December 12, 1893, received his B.S. from Princeton University in 1915 and Ch.E. from Lehigh University in 1917.

In the early part of 1917 he was employed by the American Cyanamid Co., Niagara Falls, Ont., Canada, and later that year enlisted as private in the U. S. Army Air Service, Technical Section, A.E.F. and in 1918 served as 1st Lieutenant in charge of chemical work, coating of fabrics, etc., with headquarters in London and Paris. Following his discharge in April 1919, he became Sales Engineer for the Buffalo Foundry Machine Co.

Professor Drinker is the joint author of a report on Aviation Chemistry; also a paper on the use of electric precipitation for quantitative determinations and microscopy, as well as many technical papers published in various engineering journals and the Transactions of scientific societies.

Professor Drinker has been an active member in the Society since 1922, serving on the Committee on Research from 1927-29 and on numerous technical committees. In recent years he has been a member of the Technical Advisory Committees on Air Conditioning and Its Relation to Public Health; Atmospheric Dust and Air Cleaning Devices (including dust and smoke); and on Atmospheric Impurities and Resulting Safety and Health Requirements. At present he is serving on the Committee on Engineering and Its Relation to Public Health and the Air Conditioning in Industry Committee.

Professor Drinker is well known for his studies on ventilation, illumination, microscopy, physical chemistry and physiology; also pharmacology of gases, dusts, fumes and smokes; cellulose acetate and dopes; zinc toxicity, humidity control in residences, dust masks, artificial respiration and air conditioning. He is probably best known to the public as the inventor of the iron lung.

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Axel Marin was born in Manistique, Mich., March 10, 1896, where he received his early educational training. Following his graduation from the Manistique High School he entered the University of Michigan, Ann Arbor, from which he received his B.S. and M.E. in 1922. After his graduation he became an instructor in mechanical engineering at the University and in 1934 became Associate Professor, which status he now maintains.

Professor Marin became a member of the Society in 1935 and has been active in Society affairs. In a paper by Professor Marin, which he presented before the Society, he discusses the influence of stack effect on the heat loss in tall buildings. He is at present serving on the Technical Advisory Committee on Air Distribution and Air Friction.

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Alfred Edwin Stacey, Jr., was born on March 10, 1885 at Elbridge, N. Y. He received his preparatory education at the Munro Collegiate Institute and his M.E. degree from Syracuse University in 1906.

Following his graduation from the University he was employed by the Buffalo Forge Co., Buffalo, N. Y., as engineer, and in 1908 went with Carrier Air Conditioning Co., New York City, as chief engineer. In 1909 he became vice-president of the Elbridge Chair Co., Elbridge, N. Y., and after two years returned to the Carrier Air Conditioning Co., as western manager and engineer of the Chicago office, where he remained until 1919 when he moved to Newark, N. J. as chief of research at Carrier Engineering Corp. In 1928 he was made vice-president in charge of research, and later served in the capacity of technical sales advisor as well as vice-president. In 1935 Mr. Stacey, with A. C. Buensod formed Buensod-Stacey Air Conditioning, Inc., New York, of which he is vice-president. He is Lieut. Commander, U. S. N. R.

Mr. Stacey has been active in Society activities, serving as a member of the Executive Committee of the Committee on Research, chairman of the Technical Advisory Committees on Air Conditioning in Industry, as chairman of the Committee on Transportation Air Conditioning, on Sound Control and on Corrosion. He is the author of many papers on air conditioning and associated subjects and has appeared before many technical and scientific societies.

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Jerold H. Van Alsburg was born in Charlevoix, Mich., October 2, 1903, where he received his preparatory training. In 1920 he was employed by the Bolhuis Lumber and Mfg. Co., Holland, Mich., dividing his time between drafting, designing homes and cost work. In 1922 he went with the Holland Furnace Co., and after serving in various departments, he entered sales and engineering work, and later supervised the design and installation of home and school installations, in Massachusetts and Long Island as branch manager.

In 1929 he joined the Hart and Cooley Mfg. Co., Holland, had charge of service work and assisted in experimental and development work. His later work with Hart and Cooley brought him in close association with the engineering profession and he has specialized in developing many articles for unusual application in the heating and cooling fields. He has been interested in the work of the *National Warm Air Heating and Air Conditioning Association*, and was chairman for the first three years of their educational program which consists of the short course at Michigan State College and still serves on this committee.

Mr. Van Alsburg became a member of the Society in 1931 and has taken an active interest in Society affairs. He has been chairman of the Technical Advisory Committees on Air Distribution and Air Friction since they were organized and is serving on the Transportation Air Conditioning Committee, and is a member of the Executive Committee of the Committee on Research.

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James Herbert Walker was born on March 9, 1890, Detroit, Mich., and received his early training in the Detroit schools, attending Detroit University School. He received his M.E. from the University of Michigan.

He has been with the Detroit Edison Co. since 1912, where he has specialized in central heating. He has served in various positions with the company and is now engineering assistant to the general manager.

Mr. Walker has been an active member of the Society since 1916, and has served on numerous committees throughout the past years, and at present is serving on the Executive Committee and as chairman of the Finance Committee of the Committee on Research, as well as on the Technical Advisory Committees on Climate and Season, Cooling Load in Summer Air Conditioning, Summer Air Conditioning for Residences, and on Heat Requirements of Buildings. He has served as chairman of the Guide Publication Committee, on the Council of the Society 1938-40, and as representative for the Society on National Research Council in 1937.

He is the co-author of a book on Heating and Air Conditioning with John R. Allen; and co-author with Sabin Crocker of Piping Handbook.

Mr. Walker is also a member of the *ASME*, *ASTM* and past president of the *National District Heating Association*.

Forced Circulation Hot Water Heating Subject at Minnesota

January 8, 1940. One hundred and five members and guests gathered for dinner at Minnesota Union preceding the first meeting of the year, which was called to order by Vice-Pres. M. H. Bjerken.

Following a discussion on the Society's Annual Meeting in Cleveland, Mr. Bjerken turned the meeting over to D. M. Forfar, who in turn presented the speaker of the evening, R. E. Moore, Chicago, Ill. Mr. Moore gave an interesting presentation on forced circulation hot water heating, omitting the usual technical terms which was enjoyed by all.

The meeting was adjourned at 9:15 p. m., but Mr. Moore was detained for nearly an hour by interested questioners who finally left feeling their evening had been well spent.

Dr. Ferderber Addresses Ontario Chapter

January 8, 1940. The regular meeting of the Ontario Chapter was held at the Royal York Hotel, where dinner was served to 55 members and guests preceding the meeting.

The minutes of the previous meeting were accepted as written, and Pres. H. D. Henion announced that H. B. Jenney would act as chairman, representing the Chapter in the matter of the heating laws for the City of Toronto, and urged that all members give this law their full support.

The 46th Annual Meeting of the Society in Cleveland was announced, and E. R. Gauley was appointed chairman for making arrangements for the members attending the meeting.

J. P. Fitzsimons will act as chairman of the papers committee, to fill the vacancy caused by the resignation of J. H. Fox, who has enlisted in the Army.

It was announced that H. R. Roth and C. Tasker, would represent the Ontario Chapter at the Cleveland Meeting as delegate and alternate, respectively. They will also serve in the same capacity on the Nominating Committee of the Society.

President Henion then introduced the speaker of the evening, Dr. M. B. Ferderber, Pittsburgh, who gave an extremely interesting talk on the practical application of air conditioning in the field of medicine, which he illustrated with slides. An active discussion followed and Mr. Tasker extended a vote of thanks to Dr. Ferderber in behalf of the Ontario Chapter.

Christmas Party of Western New York Chapter

December 18, 1939. The annual Christmas party of the Western New York Chapter of the Society was held at the University Club, in conjunction with the Air Conditioning Council of Buffalo, and 85 members and guests were in attendance.

The minutes of the previous meeting and the reports of the various officers and committees were postponed until the January meeting.

L. P. Saunders and C. A. Gifford were appointed as representative and alternate to serve on the Nominating Committee of the Society at the Cleveland meeting.

Mr. Gifford announced W. H. Driscoll as the speaker at the January meeting, and the subject for discussion amputating the square foot.

The meeting was then turned over to Joseph Davis, S. V. Strouse and D. J. Mahoney, under whose direction the party was held. C. W. Farrar read several telegrams, after which the spirit of Christmas prevailed, and the members and guests enjoyed a delicious luncheon, according to the report by Secretary H. C. Shafer.

Climate the Subject at Southern California

December 12, 1939. The December meeting of the Southern California Chapter was held at the Royal Palms Hotel, Los Angeles, with Pres. J. F. Park presiding. The coffee time speaker was Bill Holliday, who spoke on summer temperature in Southern California, and the wide variation in temperature within a few miles of Los Angeles. He pointed out that an air-cooled condensing unit in the desert has only one-third the capacity of a unit in Santa Monica. This was followed by group singing which was led by "Tiny."

An announcement was then made of the recent death in an airplane accident of Theodore J. Steiner, one of the chapter members.

Following the reading of a notice from the headquarters' office of the Society regarding the 46th Annual Meeting in Cleveland, a motion was made and passed appointing the President of the local chapter as delegate to the Meeting.

Dr. Ford A. Carpenter was then introduced by President Park as the guest speaker of the evening. Dr. Carpenter chose man-made vs. nature-made climate as the subject of his talk which he accompanied by a large number of projected pictures, covering a great range of time and distance of weather measurements, which was followed by adjournment.

New Orleans Organizes Delta Chapter

After several months of preliminary work Society members in New Orleans and vicinity held a meeting November 24, 1939, to organize the Delta Chapter of the Society. The petition for a charter was submitted to the Council, and officers were elected as follows:

President—G. E. May
Vice-President—C. B. Gamble
Treasurer—G. C. Kerr
Secretary—F. G. Burns
Board of Governors—John Devlin, J. J. Friedler, Jr., and L. S. Weil.

At this first meeting in the St. Charles Hotel, New Orleans, 40 members and guests were present, and among the out of town guests were, Charles F. Leopold, Philadelphia, Harvey G. Chapin, Chicago, and A. V. Hutchinson, secretary of the ASHVE, New York.

The Council voted favorably upon granting the charter to the

Delta Chapter Officers

G. E. May
President

C. B. Gamble
Vice-President

G. C. Kerr
Treasurer

Delta Chapter Officers

F. G. Burns
Secretary

John Devlin

J. J. Friedler, Jr.
Board of Governors

New Orleans members for the Delta Chapter, which becomes the 29th chapter of the Society.

The Chapter has scheduled a meeting for the official presentation of the Charter for February 8, 1940, at which time it will have the newly elected president of the Society, F. E. Giesecke, who is professor emeritus heating, ventilating, air conditioning at the A. & M. College of Texas, College Station, and also Dr. M. B. Ferderber, advisor on physiological studies at the Society's Research Laboratory, and fellow in fever therapy, department of industrial hygiene, College of Medicine, University of Pittsburgh.

Philadelphia Chapter Talks About Cigar Making

January 11, 1940. The annual dinner meeting of the Philadelphia Chapter was held at Kugler's Arcadia Restaurant in the English Banquet Hall. Pres. R. F. Hunger called the meeting to order, but immediately a motion was made, seconded and carried, that the reading of minutes and all business be dispensed with. Two reels of moving pictures depicting scenes at the chapter golf meeting were shown by E. H. Dafter, which was followed by a variety of entertainment. The meeting adjourned at 10:15 p. m.

December 14, 1939. The regular meeting of the Philadelphia Chapter was held at the Engineers Club of Philadelphia with 61 members and 14 guests in attendance. Pres. R. F. Hunger called the meeting to order and called upon M. F. Blankin, chairman of the committee on incorporation, who announced the consummation of their work and asked that the committee be discharged. This request was unanimously granted and the committee was given the thanks of the chapter.

The president then opened the first meeting of the incorporated chapter by calling for the reading of the minutes of the November meeting, which were approved as read. The treasurer's report followed, and C. B. Eastman, chairman of the membership committee, then announced the status of the membership.

H. B. Hedges gave a preview of the January meeting, and after discussing several items before the chapter he introduced R. D. Touton, technical adviser of the Bayuk Cigar Co. Mr. Touton gave a summary of his experiences with tobacco air conditioning in Sumatra and illustrated his talk with motion pictures, which were interesting and instructive. Following a discussion on the subject the meeting was adjourned.

Montreal Members Meet

October 16, 1939. The October meeting of the Montreal Chapter was attended by 20 members. Following dinner the meeting was called to order by Vice-Pres. W. U. Hughes, and the minutes of the May meeting were approved as read.

G. L. Wiggs paid tribute to the services rendered to the Chapter since its inception by C. W. Johnson and proposed that he be appointed to fill the vacancy for the office of president. This motion was unanimously carried, and F. G. Phipps was proposed and seconded to fill the office of secretary, and J. A. M. Robertson was named to fill the vacancy on the Board of Governors.

A discussion on the subject of the 1939-40 program took place, and Mr. Wiggs explained the function of the Speakers' Bureau of the Society and announced the visit of Prof. F. E. Giesecke at the November meeting.

A motion was made and seconded, that all members engaged in military activities be carried on the rolls of the chapter without payment of chapter dues until the termination of such duties. J. D. Ross raised the question as to whether the Montreal Chapter, as a unit, should offer its services to the Government. Vice-president Hughes suggested that further information be obtained before definite action be taken.

Following adjournment of the meeting motion pictures of the Khandahar ski run and the new hotel development at Mont Tremblent, and also skiing pictures taken near Quebec City were shown by Mr. Wiggs, and were greatly enjoyed by the members and guests.

W. H. Driscoll Guest at St. Louis—Modern Trends in Automatic Heating Discussed

December 12, 1939. The regular meeting of the St. Louis Chapter was held at the Kingsway Hotel, with dinner preceding the meeting which was attended by 59 members and guests.

Following dinner Pres. R. J. Tenkonohy called the meeting to order, and the minutes of the previous meeting were accepted as read. President Tenkonohy announced that a request was received from the Mayor of St. Louis to the Joint Council of Engineering Societies to review the work that has been done under the present smoke ordinance, as well as consider the possibility of making additional suggestions toward the ultimate solution of this problem. President Tenkonohy further explained that four members of the Society had been appointed to serve on a committee of the Joint Council of Engineering Societies to discuss the question and report back to the Mayor.

C. E. Hartwein, chairman of the program committee, reported on pending arrangements for future meetings.

The guest speaker of the evening, W. H. Driscoll, New York, past president of the society, gave an entertaining talk on the subject of amputating the square foot, which was thoroughly enjoyed, and a lively discussion followed. The meeting was adjourned at 9:40 p. m.

November 7, 1939. Sixty-six members and guests gathered at the Kingsway Hotel for the November meeting of the chapter. The minutes of the October meeting were approved as read, followed by reports by the treasurer and chairman of the membership committee.

J. H. Carter, chairman of the attendance committee, attended the Fall Meeting of the Society in Atlanta and reported on the meeting, and particularly paid tribute to Carl F. Boester, secretary of the chapter, for his talk at the meeting.

James R. Scott, Toledo, Ohio, was the guest speaker of the evening, selecting as his subject the modern trends in automatic heating and air conditioning. Following an interesting discussion the meeting adjourned at 9:45 p. m.

F. E. Giesecke Luncheon Guest at Washington, D. C.

F. E. Giesecke, 1st vice-president of the Society and professor of heating, ventilating and air conditioning at the A. & M. College of Texas, was the guest of honor at a luncheon at the Cosmos Club arranged by T. H. Urdahl, to discuss matters of mutual interest in cooperative activity. Other guests at the luncheon included Commander F. W. Reichelderfer, chief of U. S. Weather Bureau, Dr. H. C. Dickinson, Bureau of Standards, R. K. Thulman, Federal Housing Administration, P. A. Croney, U. S. Housing Authority, O. L. Baublitz, R. Skagerberg and C. S. Gladden, members of the management review section, U. S. Housing Authority.

The discussion centered around means by which the Society could give assistance through its Committee on Research and sub-committees to various Government bureaus which are concerned with problems both physiological and technical, pertaining to heating, ventilating and air conditioning. It was brought out that the analysis of requests for specific information from the Bureau of Standards might benefit through the cooperation of one or more of the Society's committees in suggesting data other than those specifically requested, which could be obtained through the same experimental set-up at no additional cost, and thus broaden the scope of the work. The value of informal discussion representative of professional and industrial interests was also stressed.

Many of those present, though related in activity, had never met before. In the course of discussion, the small residence built for test purposes at the Bureau of Standards to investigate various means of heating small houses and their respective efficiencies was mentioned, as were local problems concerning climatic data. A valued and immediately tangible result of this discussion was the proposal to place a weather station at the test house, so that exact conditions of temperature, humidity and air movement could be observed and recorded on the spot in connection with any tests carried on. This was accomplished through the cooperation of Commander Reichelderfer and Dr. Dickinson. Since the meeting, this matter has been followed up by the necessary exchange of correspondence to assure the establishment of this station.

T. H. Urdahl Guest at Pittsburgh

January 8, 1940. The January meeting of the Pittsburgh Chapter was called to order by Pres. F. C. McIntosh in the Roosevelt Hotel, with 43 members and guests present.

Following the reading of the minutes of the previous meeting, which were approved as read, President McIntosh announced the appointment of the following committees and committee chairmen:

Advisory—M. L. Carr, J. F. Collins, Jr., P. A. Edwards, F. C. Houghten, C. M. Humphreys, A. F. Nass and R. B. Stanger.
Program—H. B. Steggall, general chairman; J. E. McLean, C. E. Sparks, P. C. Strauch and G. O. Weddell.
Attendance—F. B. Mahon.
Greeting—E. H. Riesmeyer Jr.
Membership—B. R. Small.
Finance—H. A. Beighel.

The speaker of the evening was T. H. Urdahl, consulting engineer, Washington, D. C., who gave an interesting talk on the engineer as a referee. He reviewed the legal fundamentals of contracting, the status of the engineer, and some of his own experiences as a referee. Following an instructive discussion the meeting adjourned with a rising vote of thanks to Mr. Urdahl.

December 11, 1939. Pres. R. A. Miller called the meeting to order at the Roosevelt Hotel, with 45 members and guests present, and the minutes of the November meeting were approved as read. President Miller introduced a few out of town guests, and then announced the appointment of T. F. Rockwell, delegate, and C. M. Humphreys, alternate, to the conference of local chapter representatives at the Cleveland Annual Meeting. J. F. S. Collins, Jr., and F. C. McIntosh were appointed as delegate and alternate respectively, on the Nominating Committee of the Society.

Retiring president Miller made a brief annual report before proceeding with the election of officers.

The nominating committee reported the following as the officers elected for the 1940 season:

President—F. C. McIntosh
Vice-President—E. C. Smyers
Secretary—T. F. Rockwell
Treasurer—L. S. Maehling
Board of Governors—R. A. Miller, *chairman;* R. J. J. Tennant and G. G. Waters.

The new officers were then duly installed and President McIntosh outlined his program for the coming year.

Dr. M. B. Ferderber was called upon to speak briefly on the research program at Presbyterian Hospital on cold therapy.

At the conclusion of the meeting colored motion pictures of the New York World's Fair were shown through the courtesy of B. J. Kaiser, who took the pictures of the Fair. The meeting adjourned at 11:00 p. m.

Heating Systems and Boilers Subject Before Cincinnati

December 12, 1939. The regular meeting of the Cincinnati Chapter was well attended, with 53 members and guests enjoying dinner in the Mirror Room of the Netherland Plaza. Dinner was followed by a splendid discourse on heating systems and boilers for housing projects by W. E. Bodenstein, consulting engineer for the Government's project "Laurel Homes." Mr. Bodenstein has been retained for two additional housing projects to be built in the near future. He had much design and operating data available on heating systems which greatly interested his audience. His talk was followed by a lively discussion and a rising vote of thanks.

The minutes of the November meeting were read and approved, and a tentative standard for simplified radiator sizes was read and referred to the legislative committee.

Pres. H. E. Sproull then discussed the Society's Annual Meeting in Cleveland, which was followed by adjournment.

Illinois Meetings

December 11, 1939. The December meeting of the Illinois Chapter was called to order by Pres. Tom Brown with 75 members and guests present.

After motion to dispense with the minutes of the preceding meeting, A. O. May, chairman of the membership committee, introduced several new members.

President Brown then called attention to the program scheduled for the January meeting and reminded the members of the Annual Meeting in Cleveland.

Dr. R. W. Keeton, head of department of medicine, University of Illinois, was then introduced. Dr. Keeton opened his remarks by giving an outline of the background of the research work conducted by the University in conjunction with the Committee on Research of the Society. This resumé included facts on the use of air conditioning in hospitals, the work done to date, investigative problems in the hospital air conditioning field, and proposed extension of equipment for use in investigating these problems.

Dr. Keeton introduced Prof. A. E. Hershey, department of mechanical engineering at the University, who discussed the importance of the mean radiant temperature of the surroundings as one of the factors necessary in describing a physical environment. He also described the principle and method of calibration of three instruments for measuring this temperature, the eupatheoscope, the thermal-indicator, and the globe thermometer.

Prof. M. K. Fahnestock, also of the department of mechanical engineering, followed with a discussion of the use of the in-

struments described by Professor Hershey. Tests were made and three different methods of heating rooms were used, which resulted in data including a comparison of the equivalent and mean radiant temperatures with the dry-bulb temperatures under these methods.

Dr. Ford K. Hick, of the department of medicine at the University, was next to be introduced. Dr. Hick correlated the engineering facts covered by the two previous speakers with their significance from the medical standpoint. He also presented data on tests with healthy young adults as subjects which tend to indicate circulatory abnormalities were a response to excessive heat and that such abnormalities constitute heat exhaustion.

A general discussion followed during which many questions were brought up, both on the medical and engineering side of the work being carried on at the University in cooperation with the Society's Research Laboratory.

November 13, 1939. The regular monthly meeting was called to order by the President with 88 members and guests in attendance.

After the minutes of the October meeting were read and approved, the secretary gave his report, and then read a letter from the newly organized Oregon Chapter of the Society, expressing their appreciation for the letter of congratulations on their founding sent by the Illinois Chapter.

Following the report of the chairman of the membership committee, V. L. Sherman, chairman of the meetings and publication committee, announced the program for the December meeting.

Following announcement of the American Management Association and the Air Conditioning Conferences, President Brown gave a brief outline of the Fall Meeting of the Society in Atlanta. He then introduced the guest speaker of the evening, J. R. Vernon, Chicago, past president of the Chapter, whose efforts made possible the Illinois Chapter directory, which was distributed to the members. Mr. Vernon spoke on the automatic temperature control for air conditioning systems, which he illustrated by means of lantern slides, showing certain fundamental control principles and actual devices as manufactured by various temperature control firms. Basic instruments were described first, and their application was traced from the simpler uses in heating and ventilating down to the more complex requirements.

In closing Mr. Vernon entered a plea for adequate control systems for air conditioning installations, pointing out that the right type of control plant, carefully thought out and painstakingly installed, may serve as an adequate mechanical brain for the installation.

October 9, 1939. The first meeting of the 1939-40 season was called to order by the President with 66 members and guests present. Following the ordinary routine of business, President Brown announced the personnel of the various standing committees for the new year and called on Mr. Sherman, who reported on the activities of the meetings and publications committee.

John Howatt introduced the speaker, L. D. Gayton, chief engineer for the city of Chicago, whose subject was ventilation of underground structures including subways. Mr. Gayton traced man's progress in the art of tunnel building from the days of the early Romans up to the present day, and described the methods of ventilation employed through the ages, from merely vertical shafts to the elaborate mechanical systems in use today. He pointed out that science has discovered many things and the tunnel builder is concerned not only with supplying sufficient fresh air for the needs of the workman, but with the removal of heat, of gases resulting from the use of explosives and more recently the removal of localization of rock dust caused by the use of compressed air drills.

Following the detailed discussion of the problems involved in tunnel construction, Mr. Gayton further discussed the needs for ventilation of underground structures during their actual use. He then referred to the requirements of the Holland and Lincoln Tunnels in New York, and concluded his remarks by stating that the problem of ventilating electrically operated subways and vehicular tunnels seemed to be satisfactorily met, but that in the matter of the ventilating and air conditioning of tunnels under construction, much is yet to be done.

Following Mr. Gayton's talk there was considerable discussion, which was followed by adjournment.

Motors and Their Application to Air Conditioning Discussed at Oregon

December 7, 1939. The regular monthly meeting of the Oregon Chapter, held in Portland, was called to order by Pres. J. D. Kroeker in the presence of 27 members and guests. The minutes of the November meeting were read, and President Kroeker introduced B. W. Farnes, who presented J. E. Yates, Pacific Power and Light. Mr. Yates explained the fundamental terms of electricity, which was followed by a discussion on motors and their application to the air conditioning industry by L. R. Elder. This talk was accompanied by motion pictures taken of the largest electrical shop in the world.

Mr. Farnes returned the meeting to President Kroeker who called for a report from the officers. It was then announced that vice-president T. E. Taylor was appointed as the delegate from the Oregon Chapter to the Annual Meeting in Cleveland.

Mr. Farnes gave a brief resumé of the program for future meetings, which was followed by a summary on the publicity by Cecil MacGregor, chairman of the publicity committee.

After the new business before the chapter was discussed the meeting was adjourned, according to the report by secretary C. E. Heinkel.

Panel Heating Discussed by Prof. Giesecke at Western Michigan

December 4, 1939. The December meeting of the Western Michigan Chapter was held at the Rowe Hotel, Grand Rapids, with dinner preceding the meeting which was attended by 141 members and guests.

Pres. B. F. McLouth called the meeting to order and after the reading of the minutes of the November meeting, he introduced the guest speaker of the evening, F. E. Giesecke, 1st vice-president of the Society and professor of heating, ventilating and air conditioning at A. & M. College of Texas, College Station, Tex. Professor Giesecke's talk covered several years of investigations and actual applications of panel heating in this country and in Europe. He also pointed out the future in a new conception of comfort that may result from panel heating in that colder temperatures may be carried with warmer surrounding walls and receiving heat by radiation. He also stated that the reverse may be used to an advantage in summer cooling, and mentioned that it was not his opinion that panel heating would displace the present conceptions of air conditioning, but believed that it would find favor in the lower priced homes and in localities where air conditioning is not of major importance.

An interesting period of discussion followed the address and the meeting was adjourned.

Atlanta Holds Annual Meeting

December 5, 1939. The regular annual meeting of the Atlanta Chapter was called to order by Pres. C. L. Templin at the Ansley Park Golf Club, with 59 members and guests in attendance.

President Templin, in his annual report, gave a comprehensive outline of the Chapter's progress since its formation. He spoke highly of the officers, committees and members who had helped him during his administration, and urged their continued support to the chapter.

The secretary announced that his formal report would combine the reports of all the officers and committees presented at

this meeting, and suggested that the members consider these reports as part of his annual report.

Following the report by the treasurer, who outlined the present financial status of the chapter, the activities of the membership committee were then presented.

The code committee chairman announced that the committee had been in constant contact with government authorities having to do with codes which may affect the Atlanta Chapter, and gathered data during the current year enabling them to be well prepared for any eventuality along this line.

The by-laws committee recommended changes which would simplify and clarify the by-laws, which was followed by the report on the publicity during the year.

In appreciation for his splendid work as general chairman of the committee on arrangements for the Fall Meeting of the Society, L. F. Kent was presented with a beautiful instrument, which combined the abilities of prognostication in temperature, humidity and barometric conditions. President Templin made this award, which was a complete surprise to Mr. Kent, and it was unanimously agreed that he certainly earned the appreciation which this token indicated.

The tellers of election then announced the newly elected officers for 1940 as follows:

President—T. T. Tucker
Vice-President—S. W. Boyd
Secretary—L. F. Kent
Treasurer—L. L. Barnes
Board of Governors—C. L. Templin and E. W. Klein.

A rising vote of thanks was extended retiring President Templin, and the newly elected officers were then installed, and the business meeting adjourned.

An appetizing turkey buffet dinner was served followed by a social gathering of the members, guests and their wives.

Michigan Hears Giesecke and Ford Representative

December 5, 1939. At the December meeting of the Michigan Chapter, Prof. F. E. Giesecke, College Station, Tex., first vice-president of the Society, was the guest speaker. The meeting was held at the Lee Plaza Hotel and 100 members and guests were present.

Pres. W. C. Randall called the meeting to order at 7:30 p. m. and the reports of the Secretary, Treasurer, and Membership and Program Committees' chairmen were submitted.

G. H. Tuttle introduced Fred Shuknecht of the Detroit Fire Department, who gave a short talk on the problem of the Arson Squad and then presented the sound film approved by the Board of Fire Underwriters.

President Randall then introduced Prof. F. J. Linsenmeyer, who in turn introduced Professor Giesecke, who presented an illustrated talk on radiant heating and cooling. He discussed some of the fundamental aspects of radiant heating and cited several examples where this type of heating and cooling was used in Europe. He also presented some results of tests on radiant heating panels conducted at the Texas A. & M. College. An interesting discussion followed in which Messrs. Linsenmeyer, Hogan, Goodell, Harrigan, Burch and Robertson took part.

The meeting adjourned at 10:30 p. m. with everyone giving a rising vote of thanks to the two speakers.

November 6, 1939. The regular meeting of the Chapter was held at the Administration Building of the Ford Motor Co., Dearborn, Mich., with 138 members and guests in attendance.

After dinner, President Randall called the meeting to order and reports were given by the Secretary and Treasurer.

Vice-Pres. G. H. Tuttle briefly outlined the schedule of meetings to follow and then introduced Russell Mills, Ford Motor Co., who spoke on unusual air conditioning and ventilation problems encountered in the Ford Plant. Certain phases of Mr. Mills' talks were then discussed in detail.

At 8:00 p. m. the members and guests adjourned to the Rotunda and were taken on a conducted tour of the Spring and Upset Building, Press Shop, and also the Tool and Die Building, which was most interesting and instructive to all.

Warm Air Heating Discussed at Iowa-Nebraska

November 14, 1939. The Iowa-Nebraska Chapter held its regular monthly meeting at the Kirkwood Hotel, Des Moines, with Pres. T. R. Johnson calling the meeting to order. There were 27 members and guests in attendance. The minutes of the previous meeting were read and approved, and this was followed by the report of the Treasurer.

President Johnson then read a letter from the Oregon Chapter which reported on the first meeting of the chapter.

A. L. Walters introduced the speaker of the evening, Prof. A. P. Kratz, University of Illinois, whose visit to this chapter was arranged through the courtesy of the Speakers' Bureau of the Society. Professor Kratz gave an interesting summary of results of warm air heating and air conditioning research, which he illustrated with slides. His remarks included the results of some of the experiments in the test houses constructed at the University of Illinois in 1918 and 1921, and proved most instructive as evidenced by the discussion which followed. He also discussed tests on the efficiency of various types of radiation and radiator enclosures, rates of feed for stokers and oil burners, deflecting registers, stoker and oil burner controls, efficiency of warm air duct coverings, overall efficiency of hot air furnaces, and summer cooling by water, ice and mechanical means. Following a discussion the meeting adjourned at 10:00 p. m.

October 10, 1939. The October meeting was held at the Fontenelle Hotel, Omaha, with dinner preceding the meeting which was called to order by President Johnson and attended by 26 members and guests.

Following the reading of the minutes of the previous meeting, Treas. H. W. Stanton reported to the chapter, which was followed by a plea from E. H. Danielson, chairman of the membership committee, for each member to extend his efforts to increase the membership of the chapter.

Henry Kleinkauf, chairman of the entertainment committee, stated several speakers would be available for forthcoming meetings and that definite plans were made for the November meeting in Des Moines and for the February meeting in Omaha.

Mr. Kleinkauf then introduced the guest of the evening, C. F. Moulton, chief test engineer, Nebraska Power Co. Mr. Moulton spoke from the viewpoint of the boiler room engineer and gave a very interesting address on problems in connection with the production and distribution of steam for power and processing purposes, including the management and training of power plant personnel. At the conclusion of his talk many questions were asked concerning boiler water treatment and the training of the personnel, which was followed by adjournment.

Temperature Control Discussed at Manitoba

October 26, 1939. The regular monthly meeting of the Manitoba Chapter was held at the Fort Garry Hotel, Winnipeg, with Pres. G. C. Davis presiding, and 12 members present. Following the reading of the minutes of the September meeting which were approved as read, J. B. Steele, chairman of the membership committee, reported on the membership activities and submitted two new applications.

After some discussion regarding a recent letter from the Board of Trade of the City of Toronto, in connection with the term air conditioning, the secretary was instructed to acknowledge the letter and forward copies of correspondence to New York, with a request for advice from the Council for future guidance.

President Davis then introduced the guest speaker of the evening, William Worton, C. A. Dunham Co., Ltd., who gave a

very interesting address on the subject of temperature control on sub-atmospheric heating. Following a discussion, a vote of thanks was extended to Mr. Worton, and the meeting adjourned at 10:30 p. m.

Henry L. Doherty Dies

Henry L. Doherty, engineer and public utility operator, died in Philadelphia of bronchial pneumonia, December 26, 1939. Mr. Doherty had been in poor health since 1927, as a result of arthritis, and for the past three years remained at Temple University Hospital under constant care of his physician. At his bedside were his wife, his adopted daughter, Helen Lee Eames, who took Mr. Doherty's name, and W. A. Jones, executive vice-president of the Cities Service Co., of which Mr. Doherty was founder and president.

Mr. Doherty was born in Columbus, Ohio, May 15, 1870, of English, Scotch and Irish ancestry. He was a unique figure, a leader in three important branches of American business life, gas, electric power and petroleum, but preferred to be known as an engineer.

He started his business career as office boy with the Columbus Gas Co., where after thirteen years of intensive study of the gas industry and gas company administration, he attained the position of chief engineer as assistant to the manager in 1896. He then became manager and later president of the Madison (Wis.) Gas and Electric Co.; later he was connected as engineer, manager with various gas, electric and traction companies.

In 1905 Mr. Doherty organized the Henry L. Doherty & Co., and in 1910 Cities Service Co. was organized with Henry L. Doherty & Co. as fiscal agents. At that time Mr. Doherty was made president, an office he held until his death.

Besides being a former member of the ASHVE, Mr. Doherty was a member of the *AIEE*, the *ASME*, and numerous other engineering and civic organizations, as well as many scientific and political societies, the Metropolitan Museum of Art in New York and various other organizations. In March 1938 he was elected a trustee of Temple University, Philadelphia.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 24 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge the members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by February 16, 1940, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
BAIRD, F. E., Dist. Mgr., The Trane Co., Atlanta, Ga. (*Reinstatement*)	C. L. Templin T. T. Tucker	C. E. Brockinton R. F. Hahn
BARNES, N. W., Dist. Sales Mgr., The Fulton Sylphon Co., Chicago, Ill.	S. I. Rottmayer R. P. Sunderland	W. R. Blayney A. O. May
BIBLE, H. U., Cons. Engr., Houston, Tex.	D. S. Cooper R. B. Banowsky	G. E. Olson A. M. Chase, Jr.
BLUM, R. J., JR., Sales Engr., The Kirk & Blum Mfg. Co., Cincinnati, Ohio.	G. V. Sutfin H. E. Sproull	R. E. Kramig O. W. Motz
BRUNDAGE, F. W., Mech. Engr., Stewart-Kingscott Co., Kalamazoo, Mich.	C. R. McConner W. G. Schlichting	S. H. Downs R. W. Wilson
CHASE, P. S., Plbg., Htg. Vtg. & Air Cond., Chase Co., Eugene, Ore.	B. W. Moore B. W. Farnes	H. K. Mead W. R. Burton
COLMAN, R. C., Vice-Pres., McQuay, Inc., Minneapolis, Minn.	E. H. Seelert J. R. Hall	C. L. Bensen R. L. King
EDER, J. P., Development of Htg. Controls, Walker & Eder, New York, N. Y.	Kirby Walker H. W. Fiedler	J. A. Heller J. G. Foster
ESSEX, J. L., Engr., Armco Internatl. Corp., Middletown, Ohio.	F. C. Houghten R. T. Miller	B. K. Eaton T. I. Byrd
FISCHER, F. P., Gas Sales Engr., Frank P. Fischer Engrg. Co., New Orleans, La.	F. G. Burns G. E. May	I. H. Purinton L. V. Cressy
FLUCKEY, K. N., Lab. Asst., Washington Gas Light Co., Washington, D. C.	A. E. Stack L. B. Nye, Jr.	W. H. Loving P. H. Loughran, Jr.
GUTKNECHT, FRITZ, Engr., Blattmann Weeser Sheet Metal Works, Inc., New Orleans, La.	J. J. Friedler, Jr. G. E. May	F. G. Burns L. V. Cressy
HAINES, J. E., Mgr., Modutrol Div., Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.	A. B. Newton H. F. Dever	F. L. D. Banner Thomas McDonald
HERBERT, J. S., Asst. Engr., Blue Ridge Glass Corp., Kingsport, Tenn.	Robert Ingouf (*Non-Member*) W. H. Curtis (*Non-Member*)	H. P. Gage (*Non-Member*) R. M. Boarts (*Non-Member*)
HERSHEY, A. E., Research Asst. Prof., University of Illinois, Urbana, Ill.	A. P. Kratz M. K. Fahnestock	R. B. Engdahl E. L. Broderick